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Cover Page Footnote
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ABSTRACT
Retaining students in the Science, Technology, Engineering, and Mathematics (STEM) fields has been a challenge in the United States (U.S.). More startling is the lack of diversity across most of the STEM disciplines. Underrepresented minority groups majoring and graduating in STEM are reported to be far below the national benchmark, and it is not proportionally reflected in the overall national population. To support students in STEM, New York City College of Technology of the City University of New York has designed a Peer-Led Team Learning Leadership Program (PLTL) that recruits and trains upper freshmen majoring in STEM, particularly those who are underrepresented, to facilitate peer-led workshops in foundational STEM courses in chemistry, civil engineering, and mathematics. Results showed the PLTL Leadership Program to be highly effective for first-year underrepresented minority STEM students. First-year students self-reported the peer leading experience had strongly improved their own understanding of chemistry, engineering, and mathematics concepts, and their confidence in these subject areas was significantly increased. They also indicated gains in their confidence in public speaking and in their leadership, communication, and facilitation skills.

INTRODUCTION

The United States needs to produce more science, technology, engineering, and mathematics (STEM) professionals in order to be competitive in the global economy (President's Council of Advisors on Science and Technology, 2012). Despite the growing demands for highly skilled workers, low participation and much lower graduation rates in the STEM field still affect the nation (National Center for Science and Engineering Statistics, 2015). Although strong efforts at the national and institutional levels have been made to graduate more STEM students, the STEM attrition rates still remain high, particularly for women, underrepresented minorities[1], first-generation students[2] and those with low-income (Shaw & Barbuti, 2010). According to a recent study, Chen (2013) found that of the total 28% of bachelor's degree candidates who had declared a STEM major in 2003-2004, approximately half of the candidates left the field before completing a degree. Moreover, low-performing students (having a grade point average below 2.5) were more likely to leave the STEM field by dropping out of college than high-performing students (having a GPA of 3.5 or higher). Reinforcing the lack of women represented in the STEM field, the study also found a third of the women exited the STEM courses and switched to a different major compared to a quarter of the men.

[1] African-Americans, Hispanics, American Indians/Alaska Natives, and Asian Pacific Islanders
[2] Students who are the first in their families to attend college.

Increased effort in academically supporting underrepresented minority groups in STEM is therefore imperative to meet the demands of building a strong STEM workforce in the United States. According to the National Academies of Sciences, Engineering, and Medicine (2016), "The normative culture of STEM can be a barrier for students from underrepresented groups because it often includes views of student ability as inherent or natural, related to one's genetics, and thus not amenable to improvement. Related to this view is the tendency for introductory mathematics and science courses to be used as 'gatekeeper' courses with highly competitive classroom environments that may discourage students who are new to the fields, especially women and those from minority backgrounds" (p. 23). Significantly for this paper, the National Academies of Sciences, Engineering, and Medicine (2016) also reported colleges which provide peer support to students (such as peer tutoring, learning communities, instructional strategies) have shown improvement in student outcomes. The study presented in this paper focuses on the successful results which first-year STEM student peer leaders, mainly from underrepresented groups, have achieved by being involved in a peer leadership program.

THE PEER-LED TEAM LEARNING LEADERSHIP PROGRAM

New York City College of Technology

New York City College of Technology (City Tech) of the City University of New York is a public four-year, comprehensive minority-serving institution located in Brooklyn, New York, U.S. offering 27 associate degrees and 24 baccalaureate degrees. In the fall of 2015, City Tech had an enrollment of 17,469 students of whom 3,403 were first-time freshmen. As a federally designated Hispanic Serving Institution, 32% of the students identified themselves as Hispanic, 31% as African-American (non-Hispanic), 19% as Asian/Pacific Islander, 12% as White, 1% Hawaiian/Pacific Islander, 1% as two or more races, and 4% as International students. Approximately 67% are the first in their families to attend college, 43% are born outside of the United States with 152 countries represented, 58% report a household income of less than $30,000, and 80% of the current incoming freshmen receive need-based aid (New York City College of Technology, 2015).

Peer-led team learning leadership program design

The PLTL Leadership Program at City Tech was adopted to assist in retaining students in their STEM majors, particularly those who are underrepresented minorities. The one-year retention rates for first-time, full-time, degree-seeking freshmen of African or Caribbean descent and Hispanics in associate degree STEM programs showed an average of 60% in 2014 (New York City College of Technology, 2017). With a little over half of the students being retained in its STEM programs, City Tech was compelled to find and implement effective best practices which would mitigate and change this dire trend. One of the interventions identified was the PLTL Leadership Program.

The PLTL Leadership Program actively recruits first-year undergraduates majoring in a science, technology, engineering, and mathematics discipline to train as peer leaders to lead STEM workshops. First-year students who have successfully finished Precalculus or a higher-level mathematics course and have passed an English composition course are invited to enroll in the PLTL Leadership Program during their second semester through recommendations by their professors or peers. The PLTL Leadership Program has two main components: 1) a peer leader training course, and 2) a mentoring structure through a STEM workshop practicum. The first component is focused on

training first-year STEM students, or new peer leaders, to effectively facilitate a STEM workshop by developing and strengthening their leadership skills. The second component is having new peer leaders lead their own STEM workshops under the mentorship of experienced peer leaders.

The peer leader training course

First-year students in the PLTL Leadership Program are trained through a one-semester academic course, MEDU 2901: Peer Leader Training in Mathematics. MEDU 2901 is a one-credit course which meets once a week for 50 minutes for 15 weeks. The course is mainly taught by a mathematics education professor with guest lecturers from the mathematics, chemistry, and civil engineering departments. Approximately 10-15 STEM undergraduates are enrolled in MEDU 2901 every semester and at least half of the students are in their first-year of college. The main learning objective for this course is to train students to become effective facilitators for peer-led workshops for STEM foundation courses in chemistry, civil engineering, and mathematics. The course focuses on introducing students to facilitation and communication techniques grounded in selected learning theories. These learning theories include: Tuckerman's Stages of Group Formation, Bloom's Taxonomy, Vygotsky's Zone of Proximal Development, Perry's Schema, Deci and Ryan's Theory of Motivation, and Self-Efficacy. Additionally, techniques that improve open communication, build effective group dynamics, strengthen academic motivation, and formulate good questions are integrated in each lesson. Therefore, students are given the opportunity to practice these techniques in class. Moreover, issues regarding the importance of inclusion and diversity are discussed including topics related to class, race, gender, sexual orientation, and disability. The course in itself models and replicates an ideal workshop setting for the students. Students work in groups and openly discussing the exercises or case studies. A peer will volunteer to moderate the discussions, thus replicating what an engaging and healthy workshop should resemble. Active learning engagement techniques are employed during class where students understand and observe how a particular group facilitation method can be implemented in a group. The culmination of these relevant and essential sessions prepares new peer leaders with the necessary skills and confidence to forge healthy and productive workshops and engagement with students.

Mentoring structure through PLTL workshops

The theoretical-driven techniques are put into practice by the new peer leaders once they are enrolled in the MEDU 2901 course. The new peer leaders are assigned their own workshops in chemistry, civil engineering, or mathematics at the beginning of the semester, and they are responsible for a cohort of six to twelve students. Workshops are held once a week for one hour. Rather than a one-on-one tutorial session, students attending the workshops are expected to work collaboratively on a set of modules or selected homework problems. Attendance is mandatory for the mathematics and civil engineering workshops, and students are highly encouraged to participate in the chemistry workshops. On average four peer leaders are assigned during the same workshop time. New peer leaders are supported by working alongside experienced peer leaders, who also provide guidance, encouragement, suggestions on activities, and workshop content support. This formal type of mentoring allows new peer leaders to develop leadership skills and experience in creating a successful workshop environment under the guidance of an experienced peer leader. Because of the nature of the courses and their requirements, PLTL workshop formats differ slightly for each discipline as described below.

PLTL workshops in chemistry

PLTL was implemented in the Chemistry Department as part of a multi-faceted effort to increase student success rates, to provide a recitation-style forum, and to expand the PLTL model. General Chemistry II is the focal point for implementation of the PLTL model due to the degree of mathematics involved in the course. Each semester, one of three or four sections of General Chemistry II is selected for PLTL participation by the chair of the department and the PLTL workshop coordinator. The workshop materials are developed based on both the theoretical and practical aspects of the course. Students are invited to participate in weekly PLTL workshops to receive 10% of the course grade. Students not participating in the workshops are required to complete online problems for the same allocated percentage. These problems are selected by the instructor from a pool of questions available via a web-based assignment platform, which comes packaged with the course textbook. Results have shown that giving students extra credit to attend the workshops regularly has increased attendance. These workshops are held outside of the lecture and laboratory times. The faculty surveys the students during the first week of classes to determine the most practical time to provide the workshops. Based on the most agreeable times, two one-hour sessions per week are offered. Students can attend one or both of these sessions.

Weekly workshops focus on chemistry topics including: chemical kinetics, chemical equilibria, thermodynamics, physical properties of solutions, and acid-base equilibrium. Integrated into these concepts, students are expected to solve quadratic equations, and problems that include variables and logarithms. The workshop materials are selected by the peer leaders and the faculty members on a weekly basis and work in parallel with the course syllabus. Often times, the peer leaders themselves were once workshop participants, who view the workshops as an opportunity to share their own knowledge with peers. It also presents them with the opportunity to reinforce the concepts they learned. The PLTL model is successful because it is grounded in social interactions among peers and peer leaders. Groups of six to eight students per one peer leader seem to be the most ideal ratio in chemistry thus far. A smaller working group allows the peer leader to interact more closely with the student participants. This collaboration to solve a common problem is missing with

larger group sizes. In each session, there are two to three new and experienced peer leaders present. Weekly communication between peer leaders and faculty is emphasised. Discussions can include deviations in lecture, difficulty with the assigned workshop materials, or student attendance at the workshops.

PLTL workshops in civil engineering
The Construction Management and Civil Engineering Technology (CMCE) Department offers associate degree programs in Construction Management Technology (CM) and Civil Engineering Technology (CE). All freshmen students in CMCE are required to complete Statics as a prerequisite to their design courses. The statics course provides an introduction to the concepts of force, equilibrium, section properties, and load pattern distribution. A workbook was developed as a collaboration between the faculty and the peer leaders to assist students with the key concepts in a statics workshop. The workbooks have been used for two semesters and are being revised for corrections based on the feedback received from the students and peer leaders. About sixty to ninety students enroll in Statics each semester. A student's performance in Statics is indicative of his/her success in the curriculum; without satisfactorily passing the course, it is unlikely the student will be retained in the major.

PLTL workshops in mathematics
PLTL was adopted by the Mathematics department to increase student pass rates for four foundational mathematics courses: Fundamentals of Mathematics, Intermediate Algebra and Trigonometry, Precalculus, and Calculus I. Every semester, two sections of each mathematics course are designated PLTL, and the students enrolled in these sections are required to attend an additional one-hour workshop per week. Attendance is mandatory, and a workshop grade is given that constitutes a range of 5-15% (varies by instructors) of the final grade. For each course, there is a set of 12 to 14 modules carefully designed by the faculty to engage and challenge the students. New peer leaders work collaboratively with an experienced peer leader to create an answer key for each module prior to the beginning of the semester. An average of four peer leaders is assigned to a course.

EDUCATIONALLY EFFECTIVE PRACTICES OF THE PLTL LEADERSHIP PROGRAM

The PLTL Leadership Program has intentionally adopted several high impact educational practices in its design (Tinto, 2012; Yu, 2013). The program includes a first-year seminar course (a course designed for freshmen which supports their transition to college) and also encompasses other effective strategies to promote success among first-year STEM students, particularly those who are underrepresented minorities in STEM, including females. The high impact educational practices reinforced in the PLTL Leadership Program are demonstrated as follows:

- *High academic expectations*
  Strong emphasis is placed on developing first-year students' leadership and communication skills through an intensive training course and workshop practicum. Students are expected to prepare and master the STEM content area in the workshops they facilitate. As a result, their STEM knowledge is reinforced, strengthened, and expanded (Kuh, 2008).

- *Increased critical thinking skills*

By creating a workshop environment where students can freely discuss their ideas and solutions, the peer leader provides a support system that develops the critical thinking skills of the team members, and at the same time develops his/her own critical thinking skills. Goodman, Baxter Magolda, Seifert, and King found that "academic experiences that challenged students to analyse ideas and explore their own thoughts pushed them to think critically" (2001, p. 4).

- *A community of practice with faculty and peers*
  The mentorship experience forms a community of practice consisting of faculty and peers provides strong support and high retention rates for first-year students, particularly those who are majoring in STEM. Consistent feedback and discussions are often exchanged inside and outside the classroom and workshop settings. Strong academic communities have been shown to retain underrepresented minority students in STEM (Espinosa, 2011; National Academies, 2010).

- *Service learning*
  First-year students are assigned their own STEM PLTL workshop. This "experiential service learning" tied to the MEDU 2901 training course gives students an opportunity to apply the learning theories and facilitation techniques from the curriculum and their STEM content knowledge. Kuh (2008) states that service learning experience "often challenge students to develop new ways of thinking about and responding immediately to novel circumstances as they work side by side with peers on intellectual and practical tasks, inside and outside the classroom, on and off campus" (p.15). The ongoing effort to relate and analyse what they are learning through this "real world" workshop experience creates a setting for students to give back to the college community (Brownell & Swaner, 2010).

- *Diversity experiences*
  As a culturally-diverse, minority-serving institution, City Tech students are constantly exposed to different cultures, life experiences, and world views. A cultural day is reserved in the MEDU 2901 training course to promote awareness and appreciation through a communal meal. Moreover, topics on class, race, gender, sexual orientation, and disability are discussed. The workshop setting fosters the development of intercultural experiences with diverse peers which have been found to positively benefit students

- *Public demonstration of competence*
  Not only do first-year students display their competence in STEM knowledge in a workshop setting, but additionally they become representatives of the PLTL Leadership Program. The PLTL Leadership Program and the transformation of STEM peer leaders are often highlighted at international, national, and regional conferences or local workshops through student-faculty presentations.

THE PLTL LEADERSHIP PROGRAM FOR FIRST-YEAR STUDENTS

Participants

To assess the PLTL Leadership Program, a peer leader experience survey was administered in January 2016 to 97 peer leaders who had participated in the program. Out of the 28 peer leaders who responded to the survey, 11 peer leaders indicated that they started the program in their freshmen year of college. Five males and six females responded to the survey. Nine out of eleven (82%) students are from underrepresented minorities groups in STEM as defined as African-Americans, Hispanics, American Indians/Alaska Natives, Asian Pacific Islanders, and women. Four students are or were majoring in Applied Mathematics, two in Construction Management and Civil Engineering, and one in each of the following areas: Electrical Engineering Technology, Computer Systems Technology, Mechanical Engineering Technology, Nursing, and Radiologic Technology and Medical Imaging. Eight of the respondents are continuing with their undergraduate STEM pursuits. One respondent is in a Master's Degree program in Mathematics and two are in doctoral programs; one in Applied Mathematics and the other in Mathematics Education. The average number of semesters of being a peer leader was four.

Data analysis

Students were asked to respond to statements before and after their peer leading experience. A Likert scale with one indicating "not very much," with three as "somewhat," and with five as "a lot" was used.

Overall, the result showed that the average after peer leading experience responses were higher and more robust than before the peer leading experience responses. Table 1 displays the mean responses and standard deviations of the degree of impact before and after peer leading experience.

Table 1
Mean, standard deviation, and average difference of the degree of impact before and after being a peer leader

The Peer Leader Experience	Mean (Standard Deviation) of Degree of Impact *(1 = not very much, 3 = somewhat, 5 = a lot)*		Average Difference
	Before being a peer leader	After being a peer leader	
1. Reinforce knowledge of engineering/ chemistry/mathematics*	3.46 (0.69)	4.64 (0.51)	1.18
2. Build confidence in public speaking*	3.09 (0.94)	4.64 (0.51)	1.55
3. Improve communication skills*	3.27 (0.79)	4.73 (0.47)	1.45
4. Promote group learning techniques*	2.55 (1.04)	4.36 (0.67)	1.82
5. Enjoy sharing my engineering/ chemistry/mathematics knowledge*	3.46 (0.82)	4.46 (0.93)	1.00
6. Consider teaching as a possible career option*	2.27 (1.56)	3.73 (1.49)	1.45
7. Increase understanding of engineering/chemistry/mathematics concepts*	3.55 (0.82)	4.73 (0.47)	1.18
8. Explain engineering/chemistry/ mathematics concepts clearly*	3.18 (0.75)	4.46 (0.82)	1.27
9. Consider applying to graduate school. *	3.36 (1.63)	4.91 (0.30)	1.55
10. Increase confidence in engineering/ chemistry/mathematics*	3.64 (0.92)	4.55 (0.69)	0.91
11. Increase leadership skills*	3.36 (1.43)	4.91 (0.30)	1.55
12. Join this program as a freshman in college. *	3.55 (1.13)	4.73 (0.47)	1.18

*$p < 0.05$, two tailed.

Since the sample size for this study was small (n=11), a paired sample t-test was used to compare the before and after responses. The critical t-values are found to be ± 2.23 for the significance level of $\alpha = 0.05$. Moreover, from the estimation of the confidence intervals, there is a 95% confidence that strong statistical evidence for the twelve statements support that the peer leading experience improve students' skills and knowledge. Results from the paired sample t-test showed statistically significant differences in attitude, confidence, and understanding. Additionally, there were statistically significant differences in leadership and communication skills before and after the peer leading experience.

The positive results from the survey showed the PLTL Leadership Program to be an effective prototype for first-year underrepresented minority students in STEM. Some peer leaders joined the program because they themselves benefitted as a workshop participant which, as a result, sparked an interest in helping others succeed. A peer leader stated the following:

> "My initial experience with PLTL workshops was as a workshop student in my Calculus II class during my first college semester. I think that it was a positive and rewarding experience being able to work with my fellow classmates. This experience allowed me to establish a friendly relationship with my group members. I was able to work on my people and group work skills. I think that working and learning within the workshop environment allowed me to be an active participant and engaged in my own learning. I remember this was my first in-class

> group work experience that I found to be helpful and rewarding. Now, I am training to be a peer leader in my second semester."

First-year students felt the peer leading experience had improved their own understanding of the concepts and their confidence in the subject areas had increased. One peer leader commented:

> "I joined the PLTL Leadership Program as a freshman. The [experienced peer] leaders from PLTL Program not only helped me in studying mathematics, but also gave me advisement in planning my courses. That made me study more effectively. PLTL Program gave me opportunities to reach out other students to expand my network. [The] PLTL Program helped me achieve excellence in my freshman year. This improved my confidence to succeed in academics because I knew someone in the PLTL Program would back me up."

The students also gained confidence in public speaking, and their leadership and communication skills improved including their group facilitation techniques. Another peer leader reflected:

> "I have gained the following from my experience as a peer leader: stronger public speaking skills, the ability to collaborate and work with others, and the ability to feel confident engaging others in conversation."

Moreover, first-year students enjoyed sharing their engineering, chemistry, and mathematics knowledge and some were considering teaching as a possible career as a result of their involvement in the program.

Students also indicated some challenges that they encountered when they peer led their first group. The peer leader's inexperience and limited leadership skills made it difficult to fully engage and motivate the students in their groups, especially when working with the apathy of certain students. Moreover, the peer leaders had to work past either their own language barriers or with international students. Although their STEM content skills were strong, peer leaders expressed that explaining the concepts clearly were sometimes an obstacle to overcome. These challenges were also common to all first-time peer leaders regardless of their academic status level.

IMPLICATIONS OF THE PLTL LEADERSHIP PARADIGM

Although the research data came from a relatively small sample size, the results reveal that the PLTL Leadership Program is of benefit to first-year STEM students, particularly those who are underrepresented in STEM. This program may be used as an instructional prototype to encourage first-year students to persist in their STEM fields. Not only is their STEM knowledge reinforced, but also their ability to communicate STEM concepts and transfer their knowledge. The PLTL model creates a supportive learning environment and supplements the faculty-centred classroom with student-led and student-oriented workshops. It is an academic training ground where peer leaders help students become active learners and critical thinkers. Perhaps the most important implication of the PLTL Leadership Program is the retention of students in the STEM disciplines and in the STEM courses. The PLTL model was implemented in chemistry, civil engineering, and mathematics in an effort to increase student performance rates and decrease withdrawal and failure rates (Hockings et al., 2008; Lyon & Lagowski, 2008; Chang & Walters, 2009; Malm et

al., 2011; Liou-Mark et al., 2015). Prior to the implementation of PLTL, the average percentage of first-year students passing these fundamental courses with a C or better was approximately half (Liou-Mark et at., 2014). This program has resulted in approximately a 10% increase in academic success of students in both introductory and upper level STEM courses and a 15% decrease in withdrawal rates. All the students who participated in the peer leadership program in their first year of college are retained in their STEM fields, and they are seriously considering pursing advanced degrees in STEM. The importance of retaining students in STEM majors is critical and necessary if the nation wants to strengthen and replenish its STEM workforce. This major effort begins with empowering and equipping underrepresented STEM students, particularly in their first-year of college.

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