The Influence Of Peer-Led Team Learning on Underrepresented Minority Student Achievement in Introductory Biology and Recruitment and Retention In Science, Technology, Engineering, and Mathematics Majors

by

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Abstract

Increasing underrepresented minority (URM) participation in science, technology, engineering, and mathematics (STEM) is of increasing national importance as the United States continues to fall behind other nations in global economic competitiveness. These students constitute a large pool of potential STEM majors at the college level, but they have been recruited to and retained in STEM programs at significantly lower rates than students from other populations. As such, President Barack Obama's President's Council of Advisors on Science and Technology (PCAST) has called on undergraduate science instructors to diversify their teaching methods and employ active learning strategies to improve students' success in introductory or "gatekeeper" courses as well as improving students' attitudes toward STEM. As a strategy that fosters active learning, Peer-Led Team Learning (PLTL) holds the potential to provide much of what PCAST deems necessary to improve URM student performance in introductory courses and retention in STEM majors. In the first of two studies presented herein, we found the PLTL model to be effective in improving scores for both URM and non-URM students in an introductory college science course. In the second study, we found PLTL to be associated with higher levels of retention among URM students. We conclude that participation in PLTL can help URM students who may struggle to identify with STEM to develop stronger STEM identities, which, along with higher achievement, may lead to enhanced retention.

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Chapter 1 – Literature Review of STEM in the United States, Active Learning, URM Students in STEM, and the Peer-Led Team Learning Model

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Abstract

Though the United States has historically been the world's leader in science and technology, its status as the preeminent nation of research and innovation is in jeopardy as other nations are now catching up (IOM, NAS, & NAE, 2007). President Barack Obama's President's Council of Advisors on Science and Technology (PCAST) has called for one million additional college Science, Technology, Engineering, and Mathematics (STEM) graduates than anticipated throughout the next decade if the United States is to remain competitive with other nations economically (PCAST, 2012). PCAST has also called for undergraduate science instructors to employ a diversification of teaching methods, particularly those that require active learning on behalf of the students. Active learning has been demonstrated to be superior to traditional, didactic lecture in terms of student achievement (Freeman, Eddy, McDonough, Smith, Okoroafor, Jordt, & Wenderoth, 2014), and students who learn actively are more likely to be confident in their abilities to succeed and motivated to persist in STEM (Graham, Frederick, Byars-Winston, Hunter, & Handelsman, 2013).

Underrepresented minority (URM) students tend to persist in STEM at lower rates than their non-URM counterparts, which is likely at least in part to be due to a lack of development of science identity; that is, they do not think of these fields as possibilities for their own careers. The Peer-Led Team Learning model is one such pedagogical approach that may improve student success and confidence in their abilities to persist in STEM as it provides students with opportunities to act as scientists in the active pursuit of knowledge and with role models who are closer to their own identities who may positively influence motivation for these students.

Importance and Status of Science, Technology, Engineering, and Mathematics in the United States

Since the Industrial Revolution, investments in science, technology, engineering, and mathematics (STEM) have been closely tied to economic growth (IOM, NAS, & NAE, 2007). The ways in which such investments have paid off are evident and profound, from safe drinking water to the technologies and procedures used in modern medicine to the infrastructure of electric power. Investments in STEM hold the power to create new industries (such as gene splicing in the biotechnology industry), promote public health, improve water and air quality, and improve our standard of living (through transportation and communication as well as disaster mitigation) (IOM et al., 2007). Scientific investment has also helped secure our homeland – examples include the development of widely varied defense technologies, manufacturing of radar and sonar detectors, and the creation of penicillin that has saved countless lives on the battlefield. These advances have also, of course, led to applications in civil society. When considering all of the roles that STEM has played in our lives, there is only one reasonable conclusion concerning its importance: that investment in STEM is critical to the quality of life here in the United States.

While the United States has historically been the leader in STEM innovation, other nations are now catching up to us (IOM et al., 2007). In 2012, the President’s Council of Advisors on Science and Technology (PCAST) cited economic projections that point to a need to produce about one million more college STEM graduates than expected at the current rate throughout the next decade if the United States is to remain the leader in STEM that it has been for decades. As of 2012, undergraduate STEM retention rates hover around 40%, and increasing the retention rate from 40 to 50% alone would generate three-quarters of the one million additional STEM graduates that are necessary. The PCAST report also points to the “underrepresented majority” – the women and members of minority groups who constitute 70% of college graduates but only 45% of college STEM graduates – as a large source of potential STEM professionals. The National Academy of Sciences argues that “broad participation matters” and that our national effort to sustain and strengthen STEM must include a strategy for recruiting and retaining members of underrepresented minority (URM) groups, who make up a much smaller percentage of college STEM graduates than they do of the general populace (2011). The racial groups that tend to be underrepresented in STEM are African Americans, Latino Americans, and Native Americans. Targeting and recruiting these students, as well as retaining them, is especially important given that they constitute an increasing proportion of Americans (PCAST, 2012). The United States cannot maintain its global dominance in STEM without making a conscious effort to target URM students as potential STEM professionals.

In addition to contributing to the million additional STEM graduates that are necessary, URM inclusion can make our scientific and engineering communities stronger. It has been documented that groups that are diverse tend to be stronger and smarter than homogeneous ones when innovation is critical, as is currently the case with global competition. By increasing diversity in our STEM workforce, we would be increasing the number of perspectives and range of knowledge exemplified (Page, 2007).

The PCAST report outlines five general strategies for increasing the number of STEM graduates in the United States:

1. Catalyze widespread adoption of empirically validated teaching practices.
2. Advocate and provide support for replacing standard laboratory courses with discovery-based research courses.
3. Launch a national experiment in postsecondary mathematics education to address the math preparation gap.
4. Encourage partnerships among stakeholders to diversify pathways to STEM careers.
5. Create a Presidential Council on STEM Education with leadership from the academic and business communities to provide strategic leadership for transformative and sustainable change in STEM undergraduate education. (2012)

The report notes that the need for the first recommendation is supported by empirical evidence of how people learn, learning theory, and assessments of outcomes in STEM classrooms. Empirically validated teaching practices include those that engage students in “active learning,” whereby students take control of their own learning and must participate in some fashion in order to learn. Active learning can improve understanding of course content as well as persistence in STEM majors (PCAST, 2012).

Active Learning and Student Achievement

The most comprehensive meta-analysis of the efficacy of active learning approaches in improving student performance in STEM courses to date was conducted by Freeman and colleagues and was published in *The Proceedings of the National Academy of Sciences* in 2014 (Freeman, Eddy, McDonough, Smith, Okoroafor, Jordt, & Wenderoth, 2014). The authors of the study meta-analyzed 225 studies that compared student performance in courses with some or all active learning versus those with only traditional lecturing. The two outcome variables that were used to evaluate student performance were (1) scores on identical or formally equivalent exams and (2) failure rates, as measured by the rates of students earning a D or F or withdrawing from the course (DFW rate). The results indicated that engaging in some degree of active learning resulted in a mean exam score increase of .47 standard deviations and that students who were exposed to only lecture were 55% more likely to fail. Neither mean exam grades nor DFW rate varied significantly by the STEM discipline that housed the course, indicating that active learning improves student performance across different STEM disciplines. Results also indicated that engaging in active learning was effective in improving student performance in small (less than 50 students), medium (51-110 students), and large (greater than 110 students) class sizes, though the effect size was largest for small classes. There were no differences in effect sizes between courses for majors versus non-majors or introductory versus upper-level courses. As the most inclusive meta-analysis of active learning approaches and student performance in STEM courses to date, Freeman et al.'s 2014 study provides strong evidence that active learning approaches improve student performance in STEM courses of all sizes and disciplines.

Active Learning and Student Persistence

Achievement in STEM courses is closely tied to retention, particularly in introductory and other courses typically taken in the first two years of college (PCAST, 2012). The first two years are the most critical to recruitment and retention of STEM majors, as students who perform poorly in introductory and other early courses are unlikely to major in that discipline. Students who play an active role in the pursuit of scientific knowledge, as compared to listening to lectures, tend to learn more, have more positive attitudes about STEM as a whole, and become more confident (PCAST, 2012). The improvement in confidence leads to greater motivation to persist in STEM (Graham, Frederick, Byars-Winston, Hunter, & Handelsman, 2013). Improvements in student persistence in STEM resulting from active learning and engagement have been well documented. For example, Felder and collegues found that students who were exposed to only lecturing were twice as likely to leave engineering and three times as likely to leave college completely as compared to students taught using methods that engaged them actively in class (Felder, Felder, & Dietz, 1998). Additionally, a study at the University of Michigan found that students who participated in research with a professor at the sophomore level were significantly less likely to drop STEM majors (Nagda, Gregerman, Jonides, von Hippel, & Lerner, 1998).

URM Students in STEM

Students who are members of groups that are underrepresented in STEM fields tend to achieve significantly poorer marks in STEM courses than other students, with the achievement gaps evident in kindergarten and only widening over time (Haak, HilleRisLambers, Pitre, & Freeman, 2014; NAS, 2011). They are also less likely to complete STEM majors once declaring them; the five-year STEM degree completion rate for White and Asian American students is 37.5%, while that rate is 22.1, 18.4, and 18.8% for African American, Latino American, and Native American students, respectively (Hurtado, Eagan, & Chang, 2010). As these latter three groups of students constitute 27.9% of the total US population but only 7.1% of the biological, biomedical, and life sciences workforce, they continue to be large potential source of STEM majors. However, while a substantially smaller portion of those who enter college intending to complete a STEM degree actually persist to degree completion, a recent review of the topic by the National Center for Education Statistics found that there was not enough evidence available to draw a conclusion about whether STEM is unique in attrition rates for any student groups, even though similar attrition rates have been reported for other disciplines (Chen, 2013).

A great deal of research supports the notion that URM underachievement is rooted at least in part in poor development of science identity (Brown, 2006; Chang, Eagan, Lin, & Hurtado, 2011; Gilbert & Yerrick, 2001). This is not surprising given that (1) URM faculty are even more underrepresented among their peers than URM students are among theirs (NAS, 2011) and (2) the typical lecture format and multiple choice tests found in STEM courses provide little exposure to actual scientific practice and thinking. Role models whom students perceive to be similar to themselves are often instrumental in motivating students to stay in STEM, so a lack of faculty role models for URM students will likely diminish the chances that URM students will retain in STEM (PCAST, 2012). Motivation itself is also closely tied to STEM retention through its mediation of self-efficacy and interest (Perez, Cromley, & Kaplan, 2014). Self-efficacy has already been demonstrated to play a role in science career commitment among URM students, and students who achieve high marks are more likely to be confident in their abilities to succeed in STEM (self-efficacy) and those who engage in active learning are more likely to be interested in pursuing a STEM major (Chemers, Zurbriggen, Syed, Goza, & Bearman, 2011; PCAST, 2012). Additionally, a conceptual framework proposed by Carlone and Johnson for understanding science identity includes three components: recognition, cognition, and performance (Carlone & Johnson, 2007). Recognition refers to the degree to which a person recognizes himself or is recognized by others as a “science person.” Cognition refers to the possession of scientific knowledge and skills, and performance is the ability to demonstrate competence. Students who learn actively can more effectively mimic the scientific processes which could improve all three components of the science identity framework, and may persist in STEM majors at higher rates through increased motivation, self-efficacy, and interest (Carlone & Johnson, 2007).

Peer-led Team Learning: A History

Peer-led Team Learning (PLTL) is one such pedagogical approach that engages students actively and has been demonstrated to improve student learning in the short term (Alger & Bahi, 2004; Gafney, 2001) as well as have a variety of long-term effects (Blake 2001; Gafney and Varma-Nelson 2007). PLTL is one of several collaborative learning strategies but differs from others in that it utilizes undergraduates as “peer leaders” to lead small-group, problem-solving workshops (Eberlein, Kampmeier, Minderhout, Moog, Platt, Varma-Nelson, & White, 2007). These peer leaders are undergraduates who have previously taken and succeeded in the course in which the students are enrolled (Tien, Roth, & Kampmeier, 2002). PLTL was first implemented in the general chemistry course at the City College of New York in 1991 with two main goals: to improve student performance in the course and increase student interest in chemistry (Woodward, Gosser, & Weiner, 1993). The pilot program's workshops took place during the normal lecture time (during one out of every three lectures), with the roughly 100 students in the lecture hall broken up into 15 groups of six to eight. These small workshop groups were led by "student leaders" who received high grades when they took general chemistry, although the referencing publication failed to include what grade in the course was required to become a student leader. Surveys showed that the students highly approved of the model and were more interested in majoring in chemistry after its implementation. The authors also noted that there was a direct correlation between performance on examinations and workshop attendance and the passing rate was substantially increased following the implementation of the model (Woodword et al. 1993). Even at its inception, PLTL showed great potential to improve scores in science courses and students' attitudes about the discipline.

Peer-led Team Learning: The Model

In the early development of this model, the pedagogical approach, unique for its utilization of student leaders, was not yet referred to as "Peer-led Team Learning." This phrase was became more common in the late 1990's, and, in 2001, a review of PLTL was published called *Peer-Led Team Learning: A Guidebook* (Gosser, Cracolice, Kampmeier, Roth, Strozak, & Varma-Nelson, 2001). The *Guidebook* was written by students, learning specialists, faculty and evaluation experts who have contributed to the development of PLTL in some way. The book describes six “critical components” of the PLTL workshop model. The first, and most prominent, component is the PLTL workshops. These workshops are integral to the model. In addition to creating a role for undergraduates as student leaders, the workshop model also requires collaboration between faculty and learning specialists who train the peer leaders in learning theory and group management. Each week the leaders work through the problems that they will lead their own groups of students through later in the week. The workshops themselves should take place after background necessary for completing the problems has been presented in another context, historically and usually during “lecture” time (Gosser et al. 2001). When implemented properly, the workshops provide an opportunity for students to work collaboratively with their peers on challenging problem-solving activities that they generally would not otherwise, all while being led by an undergraduate who was in their position just a short time ago.

The second critical component of the PLTL model is that the faculty members are closely involved with the workshops and peer leaders (Gosser et al., 2001). It is up to the faculty member to assure that the workshop materials are closely aligned with the material covered in class, and the workshops would fail if the content were not associated with what the students learn in lecture. The faculty members also often guide the leaders through the weekly problems before the leaders hold their own sessions. The authors note that after seeing how well the active learning elicited by the model works for the students, faculty members often reconsider the role and efficacy of the lecture (Gosser et al. 2001).

The third component of the workshop model is that the peer leaders have successfully completed the course and are well-trained and supervised (Gosser et al., 2001). The leaders can be differentiated from a traditional lecturer or teaching assistant in that they do not simply dispense answers to the students; rather, their role is to guide the students to work actively and collaboratively so that they may arrive at the answers themselves. Leaders should know when to help and when to not. Though the leaders may be seen as mentors and role models for the students throughout the semester, they too are undergraduates and so remain non-authoritarian (Gosser et al. 2001).

The fourth component refers to the materials that the students work on themselves (Gosser et al., 2001). They must be appropriately challenging and encourage active and group learning. Problems with an inappropriate difficulty level will disengage students, and those that do not encourage group work will fail to initiate collaborative learning and inevitably be less effective than those that do (Gosser et al. 2001).

The fifth critical component is that the "organizational arrangements" — which include the space, time, noise level, resources for teaching and group size — promote learning (Gosser et al., 2001). The *Guidebook* states that the workshops should take place in small spaces conducive to group work and discussion and specifically points out that a lecture hall will not suffice (Gosser et al. 2001). The workshops must also meet on a regular basis. The last critical component is that the institution at both the departmental and administrative levels provides logistical and financial support for innovative teaching (Gosser et al. 2001). Without the support of the institution, or organizational arrangements that make for an optimal group learning experience, PLTL cannot be successfully implemented.

Zone of Proximal Development

As PLTL has been successfully implemented throughout scores of institutions and in many different STEM courses, it is important to consider why peer leaders may be more effective at facilitating student interaction and learning than a course instructor. This difference can be thought of in terms of each student's "zone of proximal development," which Vygotsky defined as the "distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (1978). In other words, it is what students are capable of with the help of others but not by themselves. Models that utilize peer-facilitated student interaction, such as PLTL, presumably take advantage of the fact that because peer leaders are closer in their ways of thinking about course content to the students than is the course instructor, they are naturally closer to the students' zones of proximal development and can relate to and interact with the students in ways that the instructor cannot (Tien et al., 2002). The close proximity of peers to students' zones of proximal development may represent one means by which PLTL peer leaders are capable of facilitating interaction and learning more effectively than a traditional course instructor can.

Peer-led Team Learning: Documented Benefits

There are several benefits of implementing the PLTL model. Perhaps the most obvious benefit is improved scores in the course. In 2002, Tien and colleagues published research on their implementation of PLTL in an organic chemistry course at the University of Rochester. This has since become one of the most highly cited papers on PLTL. Prior to 1995, students enrolled in this organic chemistry course attended 2.5 hours of lecture and 1.25 hours of recitation per week. The recitation was led by a graduate student teaching assistant who would answer student questions and go over model problems. The recitation was instructor-centered and there was very little student-student interaction or class discussion. There were also 20 to 25 students in each recitation section. In 1995, students in the course had the option to enroll in either a standard recitation section or peer-led workshop, which met for 1.5 to 2 hours per week and consisted of only eight students per section. As recommended in the *Guidebook,* the instructor developed the workshop materials to closely follow lecture material. The workshop materials also required conceptual understanding on behalf of the students, encouraged collaboration among the students, and were appropriately challenging (Tien et al. 2002).

After quantitative analyses revealed that the students who enrolled in workshop sections performed far better than those who did not, without there being any differences in prior achievement, the traditional recitation was discontinued in 1996 and only the peer-led workshops remained thereafter. For the analyses described in their 2002 paper, Tien et al. assigned all students enrolled in the course from 1992 to 1994 (before the implementation of PLTL) to the control group, while students enrolled in the course from 1996 to 1999 were assigned to the treatment group. Across all demographics investigated (male, female, majority, minority, all), the treatment group outperformed (had a higher percentage of students earning an A, B or C than) the control group. The authors interpreted this to mean that PLTL helped develop students' conceptual understanding, which was reflected in their exam scores (Tien et al., 2002).

Syracuse University also implemented PLTL in the spring of 2011 as part of its introductory biology sequence (Snyder, Carter, & Wiles, 2015). During the fall semester of introductory biology, one four-credit course is offered that includes both the lecture and laboratory. In the spring semester, the lecture and lab are offered as two separate courses. Historically, the students who choose to enroll in the optional lab outperform those who do not. In the spring 2011 semester, students were given the option to enroll in and attend PLTL workshops that corresponded to lecture material. Excitingly, results indicated that PLTL was successful at closing the anticipated achievement gap between those who did and did not choose to enroll in the laboratory component; the students who enrolled in PLTL but not in the lab performed, on average, just as well as those who were enrolled in only the lab or both PLTL and lab (without there being any differences in prior achievement) (Snyder et al., 2015). The studies by Snyder et al. (2015) and Tien et al. (2002) demonstrate that PLTL has the potential to improve student learning and success in science courses.

Another benefit of participation in PLTL workshops for students is improved critical thinking skills. Quitadamo and colleagues studied the impact of PLTL on critical thinking skills by implementing the model in both science and math courses at a research university in the Pacific Northwest (Quitadamo, Brahler, & Crouch, 2009). The authors cited some studies that failed to demonstrate significant grade differences between students who did and did not attend PLTL workshop sessions and stated that measuring critical thinking gains through the use of the California Critical Thinking Skills Test (CCTST) could be a more reliable indicator of student learning, since critical thinking skills are an essential component of all STEM (Science, Technology, Engineering and Mathematics) courses and disciplines. The students who attend PLTL sessions also presumably utilize critical thinking skills for the workshop problem-solving activities on a weekly basis. PLTL was implemented in organic chemistry, pre-calculus, first- and second-term mathematics for elementary school teachers and discrete mathematics courses. When both science and math courses were considered, critical thinking pre- and post-test scores revealed that PLTL groups achieved a significant improvement in critical thinking skills, while non-PLTL groups did not. When these critical thinking gains were broken down by course type (science or mathematics), analyses revealed that the vast majority of gains came from the students in the science courses. These students showed critical thinking gains of 6.27 percentile points, while those in the math courses only showed gains of .95 percentile points. These results suggest that scientific disciplines, specifically, hold great potential for the implementation of PLTL in undergraduate courses to improve critical thinking skills (Quitadamo et al., 2009).

A third benefit of participation in PLTL workshops for students is increased retention in undergraduate education and STEM, a particularly desireable result since PCAST released its 2012 report (described above). Becvar and colleagues implemented PLTL in the general chemistry course at the University of Texas at El Paso (UTEP) and found strong evidence that participation in PLTL can improve student retention in STEM courses and majors (Becvar, Dreyfuss, Flores, Flores, & Dickson, 2008). Prior to the implementation of PLTL at UTEP, students in the course attended three hours of lecture per week. These students served as the control group for the study. The treatment group of PLTL students attended two hours of lecture plus two hours of PLTL workshops. The authors found that in addition to higher course success and timely graduation rates, PLTL students also had higher undergraduate retention rates each semester following general chemistry and the number of undergraduate chemistry majors increased dramatically at UTEP (Becvar et al., 2008). These results support the notion that PLTL can impact students' retention in undergraduate education and STEM majors.

Further evidence of PLTL's impact on retention in STEM comes from a study of the implementation of the approach in computer science (CS) courses at Kean University (Stewart-Gardiner, 2009). These courses were Computing Fundamentals with Java (CS0), Distributed Systems, and Systems Analysis and Design. The perceived effect of PLTL on overall performance in the CS courses and retention in STEM majors varied between the courses. CS0 students, who were generally freshmen or sophomores, were less likely to agree that PLTL contributed to their abilities to continue as STEM majors or that PLTL influenced their overall performance in the course than were students in the other two courses, who were generally juniors or seniors. Almost all of the latter students agreed that PLTL contributed to their abilities to continue as STEM majors, and all agreed that PLTL influenced their overall performance in the course. The difference in the perceived value of PLTL in influencing ability to persist in STEM or performance in the course between CS0 students and the others may be due to the fact that students in the Distributed Systems course and Systems Analysis and Design course had had much more experience with lecture-based courses than the freshmen and sophomores in CS0, and for this reason they valued what PLTL brought to the classroom. In the introduction of the paper, the authors also mentioned that PLTL had been implemented previously at Kean University in the pre-calculus course and there appeared to be no relationship between PLTL and retention in mathematics. These results suggest that PLTL may play a larger role in STEM retention in upper-level than introductory science courses, and that as with critical thinking gains, PLTL may have a greater impact on retention in science versus mathematics (Stewart-Gardiner 2009).

Related Studies

To our knowledge, no study thus far has examined whether PLTL improves scores in introductory biology for URM students by comparing students who do and don't opt to participate in the model during the same semester. Perhaps the closest was a study by Preszler (2009) that investigated whether and for whom introducing peer-led workshops in introductory biology influenced achievement. Prior to 2007, students attended three lectures per week, and in 2007 he replaced one out of every three lectures with a peer-led workshop. He found that all student groups (male, female, URM, non-URM, all) experienced an increase in rates of earning As, Bs, and Cs in the course and a drop in DFW rates as compared to students previously enrolled in the course. URM students saw a greater increase in the proportion earning As or Bs (47%) than non-URM students did (36%). The study did not, however, test whether URM students who opt to participate in the model perform better in introductory biology than those who don't in the same semester. It is also important to note that what Preszler implemented at his institution cannot be considered PLTL by strict definition because each workshop contained 19 students (not the recommended six to eight), workshop sessions were substantially shorter than recommended, and workshop leaders graded workshop reports (the PLTL program recommends not having leaders do any grading so that they are perceived more as role models than instructors).

Another study by Haak and colleagues examined whether increased structure and active learning in an introductory biology course closed the achievement gap between economically and educationally disadvantaged and non-disadvantaged students (2011). Disadvantaged students were those who were enrolled in the University of Washington's Educational Opportunity Program. The authors analyzed student performance as indicated by final grades in two quarters of lecture-intensive low-structure format, two quarters of moderate structure format consisting of in-class clicker questions and weekly practice exams, and two quarters of highly structured format that added daily reading quizzes and in-class group exercises to the moderate structure format. The highly structured format had very little lecturing and the same professor taught all six quarters. Analyses revealed that the achievement gap was cut in half with increased course structure and active learning, but again, this study did not examine PLTL as a source of either structure or active learning.

Another study by Rath and colleagues investigated the impact of supplemental instruction (SI) on performance in introductory biology and graduation rates of all students, including URM students (Rath, Peterfreund, Xenos, Bayliss, & Carnal, 2007).

While supplemental instruction is similar to PLTL in that it provides a peer-facilitated academic environment conducive to group learning, it is not integrated into the course, does not employ a learning specialist, and the leaders do not typically receive training in learning or motivation theory. The authors found that students who opted to participate in SI received higher scores in introductory biology and tended to graduate at higher rates. This effect was particularly strong for URM students (Rath et al., 2007).

The Present Studies

To our knowledge, no prior study has addressed whether the implementation of the Peer-Led Team Learning model in an introductory biology course can improve scores for URM students by comparing students within one semester. Preszler's study did not implement PLTL by its strict definition and did not compare students within one semester (2009). This is problematic because over the course of several semesters, student populations, technology, and campuses can change dramatically. Haak et al.'s study tested the influence of active learning and increased course structure on achievement gaps between disadvantaged and non-disadvantaged students, but not whether URM students saw significant improvements in their grades and not using anything similar to the PLTL model (2011). Rath et al.'s study utilized SI, not PLTL (2007).

In Chapter 2, we present a study in which we tested for the influence of PLTL on URM student achievement in Introductory Biology. Because URM students tend to struggle with science identity more so than non-URM students, we predict that URM students will benefit disproportionately from the model in terms of student achievement.

For this study, I collaborated with other authors on the overall concept of the study. Julia Snyder composed the original draft of the introductory material. I performed the statistical analyses with input from Ryan Dunk sufficient to warrant his inclusion in the author list. I also composed the initial draft of the methods and results and generated the associated figures. Jason Wiles oversaw all of these steps and edited the final draft with input from the other authors.

Additionally, no prior study that we are aware of has tested the influence of PLTL in improving the STEM recruitment and retention rates for URM students. However, given the known benefits of active learning on STEM persistence, potential benefits of active learning on science identity development, and that role models provided by the PLTL model are likely to positively influence motivation, we hypothesized that participation in the PLTL model will positively influence recruitment into and retention in STEM majors for all students—but particularly URM students who are often less likely to identify with STEM. This study is described in detail in Chapter 3. As first author, I ran all statistical analyses, coded the data on recruitment and retention, and prepared the original manuscript draft. Julia Snyder coded data on student demographics and offered input toward the manuscript draft. Jason Wiles oversaw the project and edited the final version in coordination with other authors.

Chapter 2 – Peer-Led Team Learning Helps Minority Students Succeed

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Abstract

Active learning methods have been shown to be superior to traditional lecture in terms of student achievement, and our findings on the use of Peer-Led Team Learning (PLTL) concur. Students in our introductory biology course performed significantly better if they engaged in PLTL. There was also a drastic reduction in the failure rate for underrepresented minority (URM) students with PLTL. With such compelling findings, we strongly encourage the adoption of Peer-Led Team Learning in undergraduate Science, Technology, Engineering, and Mathematics (STEM) courses.

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Background

Recent, extensive metaanalysis of over a decade of education research has revealed an overwhelming consensus that active learning methods are superior to traditional, passive lecture in terms of student achievement in post-secondary Science, Technology, Engineering, and Mathematics (STEM) courses (Freeman et al., 2014). In light of such clear evidence that traditional lecture is among the least effective modes of instruction, many institutions have been abandoning lecture in favor of “flipped” classrooms and active learning strategies. Regrettably, however, STEM courses at most universities continue to feature traditional lecture as the primary mode of instruction.

Although next-generation active learning classrooms are becoming more common, large instructor-focused lecture halls with fixed seating are still the norm on most campuses, including ours for the time being. While there are certainly ways to make learning more active in an amphitheater, peer-interactive instruction is limited in such settings. Of course, laboratories accompanying lectures often provide more active learning opportunities. But in the wake of commendable efforts to increase rigorous laboratory experiences at the sophomore and junior levels at Syracuse University, a difficult decision was made to decouple the lecture sections of the second semester course of the two-semester, mixed majors introductory biology sequence from the laboratory component, which was made optional. There were good reasons from departmental and institutional perspectives for this change. However, although STEM students not enrolling in the lab course would arguably be exposed to techniques and develop foundational process skills in the new upper division labs, we were concerned about the implications toward achievement among those students who would opt out of the introductory labs. Our concerns were apparently warranted, as students who did not take the optional lab course, regardless of prior achievement, earned scores averaging a letter grade lower than those students who enrolled in the lab. However, students who opted out of the lab but engaged in Peer-Led Team Learning (PLTL) performed at levels equivalent to students who also took the lab course (Snyder et al., 2015).

Peer-Led Team Learning is a well-defined active learning model involving small group interactions between students, along with or in place of the traditional lecture format that has become so deeply entrenched in university systems (Figure 1-adapted from Roth, Goldstein, & Marcus, 2001). PLTL was originally designed and implemented in undergraduate chemistry courses (Gosser, Roth, Gafney, Kampmeier, Varma-Nelson, Radel, & Weiner, 1996; Woodward et al., 1993) and it has since been implemented in other undergraduate science courses such as general biology and anatomy and physiology (Tenney & Houck, 2003; Wamser, 2006). Studies on the efficacy of PLTL have shown improvements in students' grade performance, attitudes, retention in the course (Gafney, 2001; Hockings, DeAngelis, & Frey, 2008; Lyle & Robinson, 2003; Tenney & Houck, 2003; Tien et al., 2002; Wamser, 2006), conceptual reasoning (Peteroy-Kelly, 2007), and critical thinking (Quitadamo et al., 2009), though findings related to critical thinking benefits for peer leaders have not been consistent (Snyder & Wiles, 2015).

PLTL and Underrepresented Minorities

Along with our concern for student success in general, we have been especially focused on closing gaps for underserved groups within our student population.

According to the National Academy of Sciences, efforts to increase the participation of underrepresented minorities (URMs) in STEM fields are essential to sustaining America's research and innovation capacity (2011). Although members of minority groups have been earning an increasing number of post-secondary degrees since the 1990s, a substantially smaller proportion of minority students choose to pursue degrees in science and engineering than do students from groups that are traditionally well represented in STEM (Aud, Fox, & KewalRamani, 2010). Increasing recruitment of underrepresented minorities into STEM fields is a necessary effort, but retaining these students in STEM disciplines must also be a priority. Aside from the obvious social justice and equal access imperatives involved, the diversity of background and talent that students from underrepresented minority groups can bring to STEM fields is essential if we are to remain technologically innovative as global economic changes demand greater numbers of STEM professionals.

With high attrition rates of STEM majors in the United States, and even higher rates of underrepresented minorities leaving STEM disciplines at the undergraduate level, there has been a significant amount of research dedicated to interventions intended to increase the recruitment and retention of students in STEM disciplines. The literature reveals several factors that affect retention of underrepresented minorities in STEM, including mentoring (Wilson, Holmes, deGravelles, Batiste, Johnson, McGuire, Pang, & Warner, 2012), learning styles and strategies (Wilson et al, 2012), earning a passing grade in gatekeeper courses (Mitchell, 2012), social networking (Mitchell, 2012), and reinforcing science identity (Hurtado, Newman, Tran, & Chang, 2010).

Students who do not fare well in introductory STEM courses are far less likely to be recruited or retained in STEM majors, and when instruction involves only traditional lecture, there is a tendency for students to feel isolated and hopeless if they are not doing well (Swarat, Drane, Smith, Light, & Pinto, 2004). The PLTL model incorporates a variety of learning styles/strategies, thus creating an environment conducive to social networking and reinforcement of science identity while developing students' own understandings of scientific concepts in more accessible terms. We would therefore expect that URM students in the context of such an environment might achieve at higher levels than in traditional settings without PLTL. Indeed, Treisman (1992) instituted a program based on small group interactions in the context of a large university mathematics course with a goal of reducing academic isolation for underachieving students. Not only did this enhance learning and achievement, but it also reduced attrition. Among African American students in Treisman's study, only 3% of the small group participants were unsuccessful in the course compared to 40% of those who did not participate and 33% in the control group.

Implementation of PLTL

In implementing PLTL to the introductory biology course we adhered to the workshop model as described by Gosser (2001). A learning specialist (in our case, a Postdoctoral scholar with training in science education) recruited students who had been previously successful in the course to be peer mentors (success is generally defined as having earned an "A" or "B"). Students who were interested and available to serve as peer mentors were awarded academic credit in lieu of monetary payment and were thus enrolled in a leader training course that met once a week for training in learning theory, group leadership methods, and conceptual content. In addition to attending the training class once a week, peer mentors led a one-hour workshop with eight or fewer students taking introductory biology.

Because this was the first time offering PLTL Workshop sessions in introductory biology at our university, students were offered a minimal amount of extra credit to attend the sessions in addition to lecture. This extra credit was disregarded in our analyses of student achievement. During an introductory biology lecture at the beginning of the semester, students were told about the opportunity to participate in small group problem-solving sessions each week with a peer leader who was already successful in the course. An email with sign-up instructions and the same information about PLTL presented in lecture was also sent out to the students. Although students voluntarily opted to participate in the peer-led workshop sessions, enrollment based on prior student-student friendship or student-leader friendship was minimized, as well as discrimination, by posting the available workshop times without the peer leaders' names or the names of the other enrolled students. It is important to note that students who opted to engage in PLTL did not differ statistically from those who did not participate in PLTL in terms of prior achievement in the previous semester.

During the first training session, peer mentors were provided with a description of the PLTL model, a first workshop agenda (at end of this chapter), and a peer leader handbook (Roth et al., 2001). Successive training sessions included activities related to the weekly reading from the handbook, debriefing on the previous week's workshop session, and collaboration of the peer mentors on weekly problem sets that coincided with the lecture content for the week.

During the workshop sessions, peer mentors guided their students through problem sets that were created through the collaboration of the learning specialist and course instructor (Workshop materials can be found here: https://sites.google.com/site/quickpltl/workshop-materials or via the link in Box 1 of the main article.). Weekly problem sets included challenging, conceptually based problems and corresponded to common topics for introductory biology and included but were not limited to such topics as photosynthesis, cellular respiration, plant reproduction and development, animal structure, and animal nutrition.

To obtain feedback on the effectiveness of the sessions, peer mentors completed weekly journals in which they reflected on the session. These reflections included feedback on group dynamics, understanding of material by the students, difficulties encountered, methods/strategies used, and types of problems that were beneficial or not-so-beneficial to the understanding of specific concepts.

The statistical test for course retention was performed using Pearson chi-squared analyses including all students whose URM/Non-URM status was known based on institutional data collected during the admissions process (N=479). In subsequent analyses, to look at the effect on PLTL between URM and non URM students, we defined adequate PLTL participation as previously determined (Snyder et al., 2015) and used Pearson chi-squared tests.

Thorough descriptions of our implementation of PLTL can be found in Snyder et al., 2015 and Snyder & Wiles, 2015.

Ethics Statement

Data reported in this manuscript were collected according to protocols approved by the Syracuse University Institutional Review Board. Prior to collecting the data, participants were provided with an informed consent form via email. Participants were able to have their data excluded from the research dataset at any time, without penalty, and without the knowledge of the researchers by contacting a non-instructor/non-researcher third party charged with managing the data. For privacy protection, each voluntary participant was assigned a unique identification number by the third party administrator which could be matched across data collection instruments.

Our Findings

Our experiences in using PLTL alongside the lecture hall experience in our introductory biology course have yielded exciting results. Among these are that retention in the course was higher for students who enrolled in PLTL, with those who did not attend PLTL sessions being significantly more likely to withdraw from the course (x^2 = 7.194, N = 479, df = 1, p = 0.007).

Perhaps even more encouraging is how PLTL appears to have influenced student achievement in the course, particularly for URMs (Tables 1-4). As shown in Figure 2, there was a dramatic and significant decrease, from nearly 40% down to about 15%, in the number of students earning Ds, Fs, or Withdrawing from the course (DFWs) among URMs who participated in PLTL (x^2 = 9.016, N = 90, df = 1, p = 0.003), and a smaller, but significant, decrease in DFWs for non-URMs as well (x^2 = 5.254, N = 251, df = 1, p = 0.022). No difference in DFW rate was observed between URM and non-URM students when both groups participated in PLTL. That is, the DFW rate was significantly higher for URMs than it was for non-URMs among those who did not engage in PLTL ($x^2 = 14.157$, N = 227, df = 1, $p < 0.001$), but not significantly different between URMs and non-URMs who did.

The results above are for all students whose URM or non-URM status could be determined (N=479) regardless of concurrent enrollment in a lab course. There was no significant difference in prior achievement between students who opted out of PLTL or lab and those who engaged in these options. The laboratory component had been previously shown to be a factor in achievement (Snyder et al., 2015), however, we also found that DFW rates were lower among URMs who engaged in PLTL whether they were enrolled in the laboratory course ($x^2 = 5.074$, N = 69, df = 1, $p = 0.024$) or not ($x^2 = 4.200$, N = 21, df = 1, $p = 0.040$). Finally, we note that for URMs who did not participate in lab, half of those who did not engage in PLTL earned Ds, Fs, or withdrew from the course, while those who did engage in PLTL all completed the course and earned grades of C or higher.

Conclusions, Recommendations, and Resources

Based on these data and on evidence from prior research, we are convinced that PLTL is effective in improving student achievement in introductory STEM courses, particularly for URM students. The drastic reduction in DFW rates among URM students is a very compelling reason to adopt the PLTL model, especially since significant gains were seen among non-URMs as well. The impact among students who are not concurrently enrolled in a lab course is a particularly important finding in the context of the biology program at our university, as several of the second-year courses in the biology major are not directly coupled with mandatory laboratory classes. What have we gained if we retain more diversity among life-science majors in their first year only to risk losing them as sophomores? It may be that a strong first year will help even the playing field looking toward the second, so our future efforts will include tracking these students into upper division courses as well as seeking to provide similar peer-interactive learning activities to students in all core courses in biology.

We also encourage other post-secondary educators to consider using PLTL, and many resources exist to help facilitate implementation in introductory biology and other STEM courses. Box 1 includes a number of helpful tools for beginning a PLTL program. We welcome inquiries regarding how we have undertaken these efforts as well as collaborations in research around this and other strategies in biology education.

Box 1: Useful Resources:

- Books

  Peer-Led Team Learning: A Guidebook. D Gosser, M Cracolice, J Kampmeier, V Roth, V Strozak, & P Varma-Nelson, eds. 2001. Upper Saddle River, NJ: Prentice Hall.
  ISBN-10: 0130288055

  Peer-led Team Learning: Origins, Research, and Practice. D Gosser. 2015. Ronkonkoma, NY: Linus Publications.
  ISBN-10: 1607975459

  Peer-Led Team Learning: A Handbook for Leaders, V Roth, E Goldstein, & G Marcus. 2001. Upper Saddle River, NJ: Prentice Hall.
  ISBN-10: 0131876058

- Free Online Resources
  - The Center for Peer-led Team Learning: https://pltl.org/
  - Workshop Problem Sets: https://sites.google.com/site/quickpltl/workshop-materials

Acknowledgements

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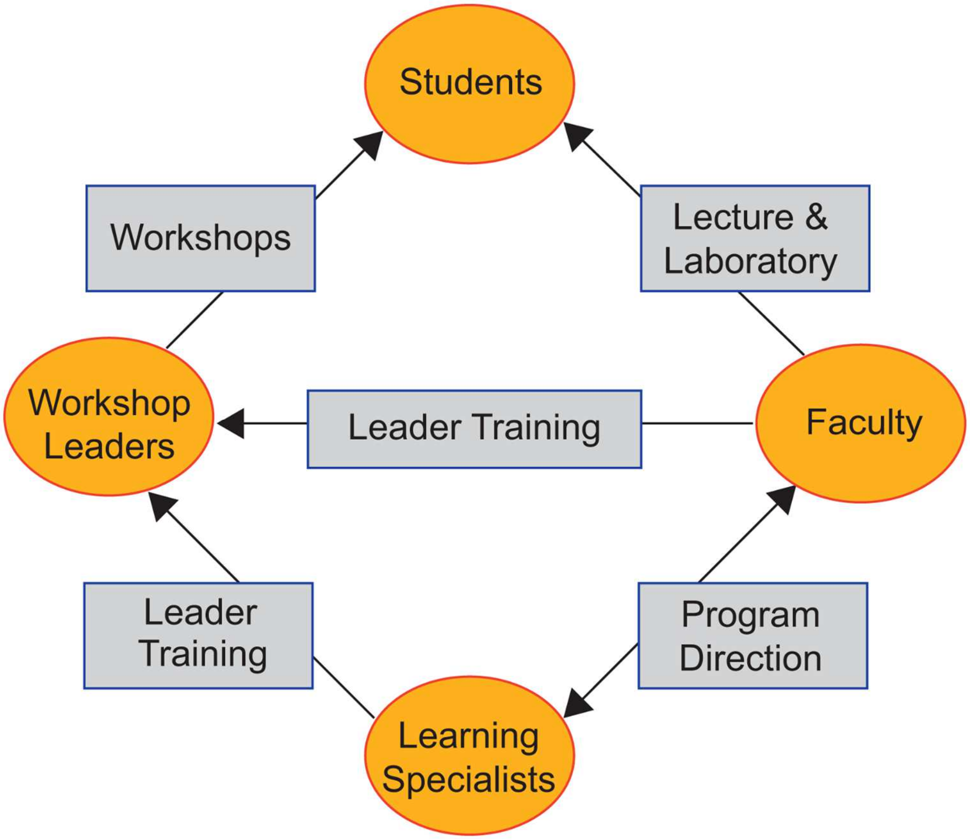
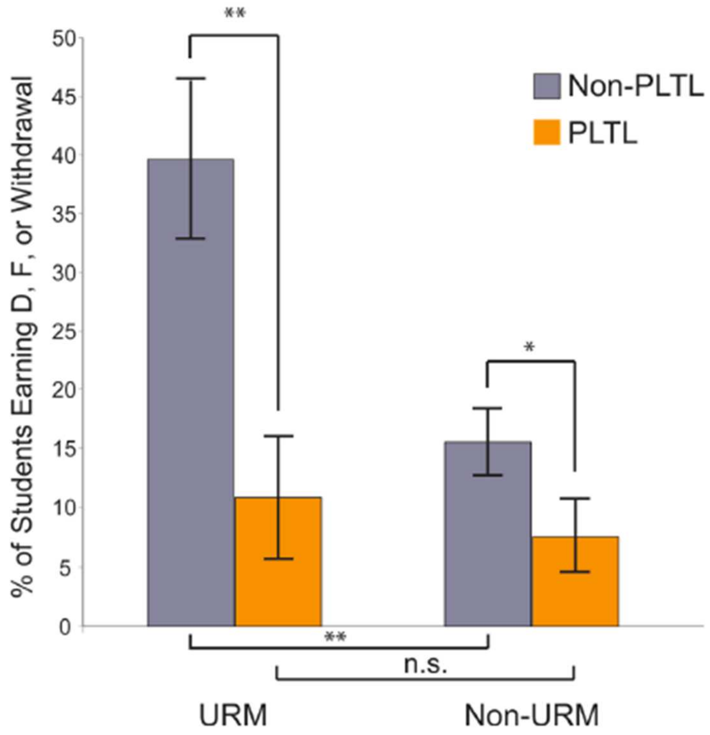
Figure 1: The PLTL model



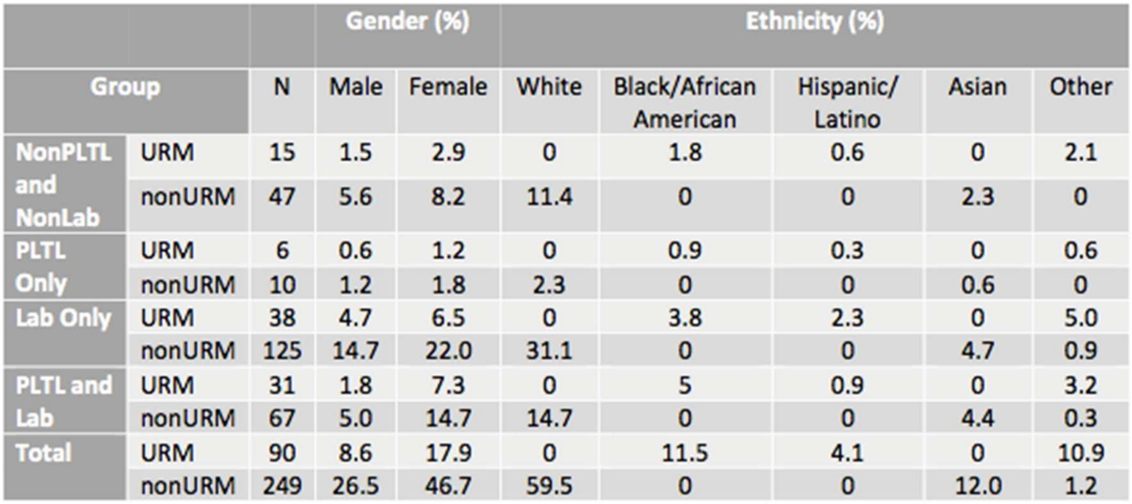
In the PLTL workshop model, students work in small groups of six to eight students, led by an undergraduate peer leader who has successfully completed the same course in which their peer-team students are currently enrolled. After being trained in group leadership methods, relevant learning theory, and the conceptual content of the course, peer leaders (who serve as role models) work collaboratively with an education specialist and the course instructor to facilitate small group problem-solving. Leaders are not teachers. They are not tutors. They are not considered to be experts in the content, and they are not expected to provide answers to the students in the workshop groups. Rather, they help mentor students to actively construct their own understanding of concepts.

Figure 2: Achievement in introductory biology for URM and non-URM students with and without PLTL



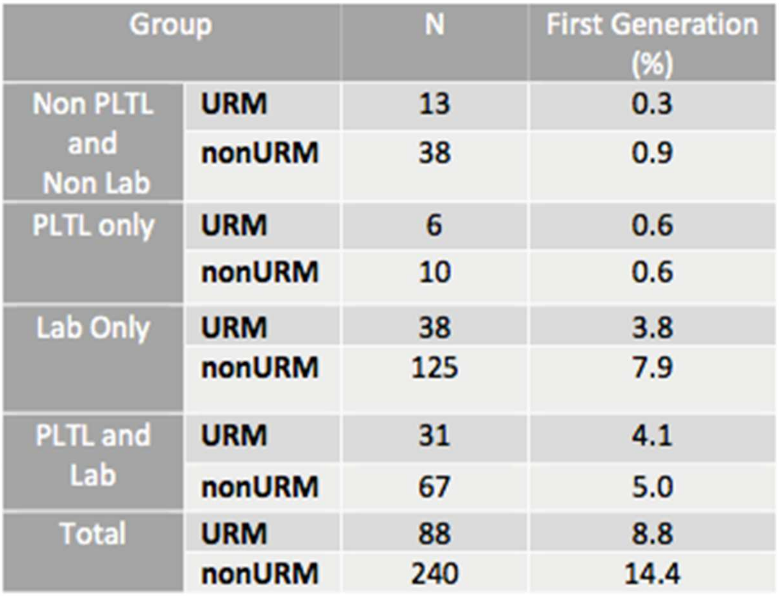
Percent of students who earned a D, F, or withdrew (W) from the course. Values represent percent +/- standard error. Chi-square analyses reveal a significant achievement gap between URM and non-URM students ($p < 0.001$) when these students do not participate in PLTL, but no difference in DFW rate was observed when URM and non-URM students participated in the PLTL model ($p = 0.272$).

Table 1: Demographics for PLTL/Lab Groups (Gender and Ethnicity)



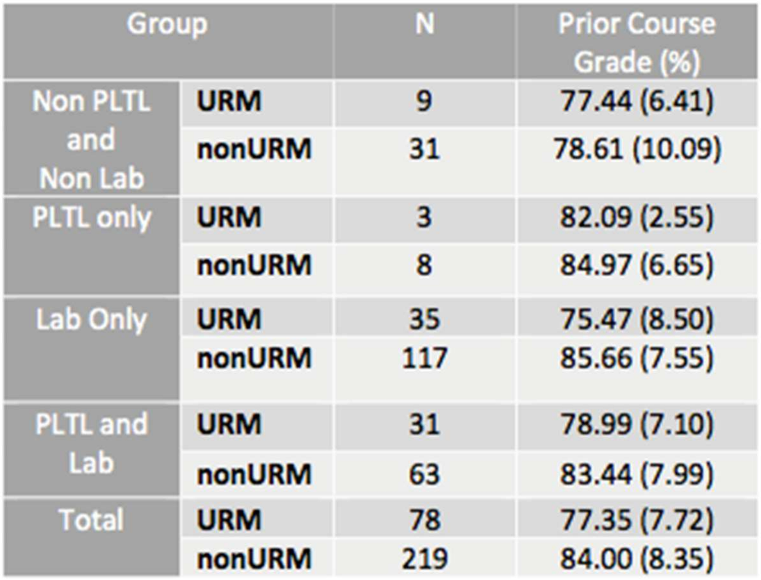
			Gender (%)		Ethnicity (%)				
Group		N	Male	Female	White	Black/African American	Hispanic/ Latino	Asian	Other
NonPLTL and NonLab	URM	15	1.5	2.9	0	1.8	0.6	0	2.1
	nonURM	47	5.6	8.2	11.4	0	0	2.3	0
PLTL Only	URM	6	0.6	1.2	0	0.9	0.3	0	0.6
	nonURM	10	1.2	1.8	2.3	0	0	0.6	0
Lab Only	URM	38	4.7	6.5	0	3.8	2.3	0	5.0
	nonURM	125	14.7	22.0	31.1	0	0	4.7	0.9
PLTL and Lab	URM	31	1.8	7.3	0	5	0.9	0	3.2
	nonURM	67	5.0	14.7	14.7	0	0	4.4	0.3
Total	URM	90	8.6	17.9	0	11.5	4.1	0	10.9
	nonURM	249	26.5	46.7	59.5	0	0	12.0	1.2

Table 2: Percent of Frist Generation Students in each PLTL/Lab Group



Group		N	First Generation (%)
Non PLTL and Non Lab	URM	13	0.3
	nonURM	38	0.9
PLTL only	URM	6	0.6
	nonURM	10	0.6
Lab Only	URM	38	3.8
	nonURM	125	7.9
PLTL and Lab	URM	31	4.1
	nonURM	67	5.0
Total	URM	88	8.8
	nonURM	240	14.4

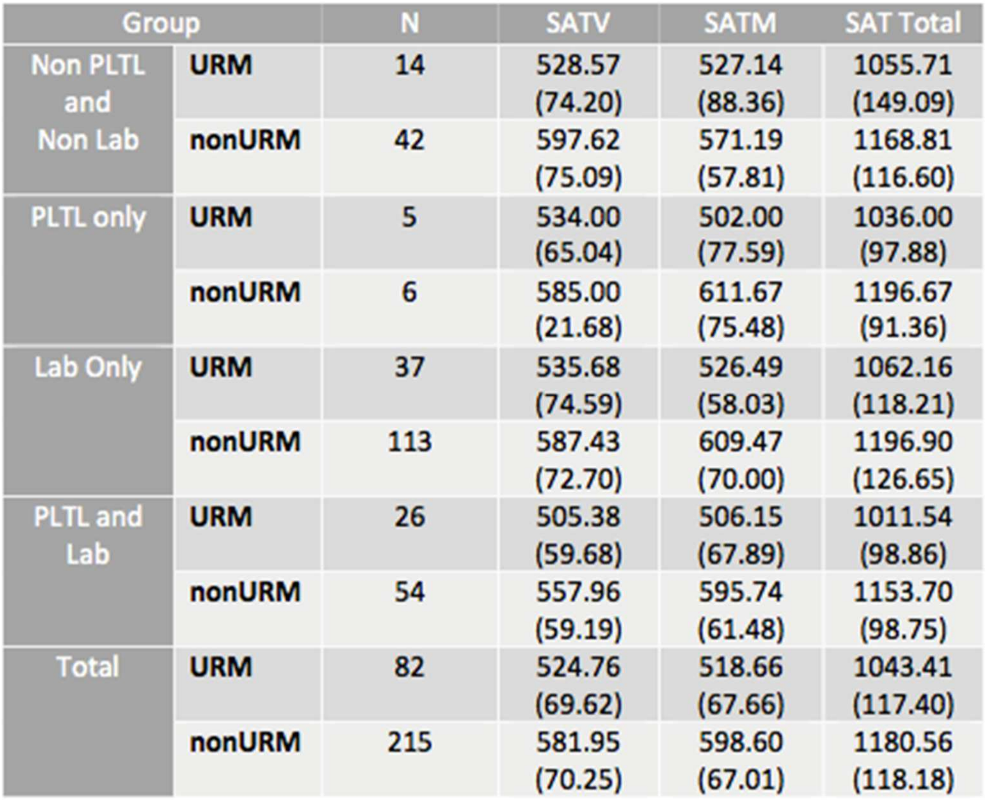
Table 3: Final Grade Performance of each PLTL/Lab Group in First Semester Introductory Biology



Group		N	Prior Course Grade (%)
Non PLTL and Non Lab	URM	9	77.44 (6.41)
	nonURM	31	78.61 (10.09)
PLTL only	URM	3	82.09 (2.55)
	nonURM	8	84.97 (6.65)
Lab Only	URM	35	75.47 (8.50)
	nonURM	117	85.66 (7.55)
PLTL and Lab	URM	31	78.99 (7.10)
	nonURM	63	83.44 (7.99)
Total	URM	78	77.35 (7.72)
	nonURM	219	84.00 (8.35)

Note. Standard deviations in parentheses.

Table 4: Mean SAT scores for each PLTL/Lab Group



Group		N	SATV	SATM	SAT Total
Non PLTL and Non Lab	**URM**	14	528.57 (74.20)	527.14 (88.36)	1055.71 (149.09)
	nonURM	42	597.62 (75.09)	571.19 (57.81)	1168.81 (116.60)
PLTL only	**URM**	5	534.00 (65.04)	502.00 (77.59)	1036.00 (97.88)
	nonURM	6	585.00 (21.68)	611.67 (75.48)	1196.67 (91.36)
Lab Only	**URM**	37	535.68 (74.59)	526.49 (58.03)	1062.16 (118.21)
	nonURM	113	587.43 (72.70)	609.47 (70.00)	1196.90 (126.65)
PLTL and Lab	**URM**	26	505.38 (59.68)	506.15 (67.89)	1011.54 (98.86)
	nonURM	54	557.96 (59.19)	595.74 (61.48)	1153.70 (98.75)
Total	**URM**	82	524.76 (69.62)	518.66 (67.66)	1043.41 (117.40)
	nonURM	215	581.95 (70.25)	598.60 (67.01)	1180.56 (118.18)

Note. Standard deviations in parentheses.

Chapter 3 – Peer-Led Team Learning Improves Minority Student Retention in STEM Majors

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Abstract

President Barack Obama's President's Council of Advisors on Science and Technology issued a report in 2012 calling for a drastic increase in the number of STEM graduates produced in our country over the following decade if we are to remain economically competitive globally (PCAST, 2012). The report cited the need to make STEM more accessible to the women and members of underrepresented racial groups who together comprise 70% of college graduates but only 45% of college STEM graduates, echoing calls by the National Academy of Sciences to expand underrepresented minority participation in STEM at the college level (NAS, 2011). In the following study, we examined whether participation in the Peer-Led Team Learning (PLTL) model in introductory biology influenced the rates of recruitment into STEM and retention in STEM for underrepresented minority (URM) students and for non-URM students. Chi-square analyses reveal that there are significant gaps in STEM recruitment and retention rates between URM and non-URM students, but when these students participate in the PLTL model, no differences in STEM recruitment or retention rates were observed. Additionally, we found that STEM retention rates were significantly improved for URM students who participated in the model.

Background

In 2012, the President’s Council of Advisors on Science and Technology (PCAST) released a report detailing the need for one million more college STEM (Science, Technology, Engineering and Mathematics) graduates than expected under current assumptions throughout the next decade (PCAST, 2012). The proportion of college graduates that complete a STEM degree has been falling for years, and the proportion of STEM graduates among college graduates is expected to continue to decline. Additionally, the National Academy of Sciences (2011) has identified minority participation in STEM as a national priority, as diversity among participants in STEM fields is necessary to ensure innovation, among other benefits, and to grow a strong and talented science and technology workforce. There is thus a great need to make STEM more accessible to the “underrepresented majority” – the women and members of Underrepresented Minority (URM) groups who constitute 70% of all college graduates but only 45% of STEM graduates (PCAST, 2012).

The first two years of college are critical for STEM persistence. Most students who leave STEM majors do so after taking introductory courses, and, moreover, even high-achieving students often cite uninspiring introductory courses as a reason for switching majors (PCAST, 2012). The PCAST report identifies three main aspects of student experience that affect persistence in STEM: intellectual engagement and achievement, motivation, and identification with a STEM field. It also emphasizes the need to adopt teaching strategies that demand active learning and can improve these facets of students’ experiences with STEM so that the United States can begin to satisfy its own workforce demands.

Peer-led Team Learning (PLTL) is a pedagogical approach that appears to provide much of what PCAST deems necessary to increase student persistence in STEM, including opportunities for intellectual engagement and achievement. Active learning has been documented to improve student learning and reduce failure rates across all STEM disciplines and class sizes (Freeman et al., 2014). PLTL is an active learning approach that employs high-achieving undergraduates as peer leaders who facilitate weekly small-group workshops, which the students have the option to attend in addition to or in place of traditional lectures. During PLTL workshops, students work collaboratively on problem sets with their peers and the peer leader. The peer leaders themselves have already taken and been successful in the course and attend weekly training sessions with a learning specialist during which they learn how to facilitate discussions and guide students to their own answers without "teaching" content (Tien et al., 2002). These workshops promote active learning and engagement on behalf of the students since the students must arrive at the answers to the problem sets themselves. Because PLTL engages students in active learning, active learning has been associated with improved achievement, and achievement in "gatekeeper courses" is closely tied to persistence in STEM, implementing PLTL in an introductory biology course may address intellectual engagement and achievement – the first aspects of student experience that PCAST indicates can affect student persistence in STEM (Alger and Bahi, 2004; Gafney, 2001; PCAST, 2012; Snyder et al., 2015). Additionally, because PLTL has already been demonstrated to improve student achievement in introductory biology, and because students at Syracuse University must earn a C+ or better in introductory biology to declare a biology major, greater rates of STEM recruitment and retention may result from PLTL participation simply because more students are eligible to declare a biology major (Snyder et al., 2016). Also, because URM students tend to achieve significantly lower grades in STEM courses than non-URM students and therefore have more potential to gain from active learning approaches, there is reason to believe that URM students may see particular benefits in their STEM retention rates when they participate in PLTL (Rath et al., 2007).

There is also evidence that instructional strategies that require active learning on behalf of the students can also impact students' motivation to persist in STEM. Esmaeili and Eydgahi (2014) reported that active learning-based courses have positive impacts on students' motivation and intention to register for STEM courses. Additionally, providing students with role models in STEM – which the PCAST (2012) report asserts is closely tied to motivation – can influence both recruitment and retention in STEM (Drury, Siy, & Cheryan, 2011). PLTL also provides opportunities for students to interact with peers from similar backgrounds, which has also been associated with motivation to persist in STEM (Ethier & Deaux, 1994). Given that PLTL requires active learning and provides students with role models in the form of peer leaders and opportunities to interact with one another, it may influence student motivation to persist in STEM. Additionally, given that there is a tendency for students to feel isolated and hopeless when not performing well in lecture-based courses, and that URM students tend not to perform as well in STEM courses as non-URM students, PLTL may hold particular benefits for URM students' motivation to persist in STEM since interacting with peers could potentially alleviate some of those feelings of isolation and hopelessness (NAS, 2011; Swarat, Drane, Smith, Light, & Pinto, 2004).

The third aspect of student experience that the PCAST (2012) report asserts can influence persistence in STEM is identification with a STEM field. Several factors have been documented to influence identification with STEM, including interactions and relationships with peers and faculty, involvement in study groups/discussing and working on course content with peers, and negative racial experiences/degree of feeling included (Anaya, 2001; Chang, Eagan, Lin, & Hurtado, 2011; Espinosa, 2011). The PLTL model provides opportunities for students to work collaboratively with one another on weekly problem sets under the guidance of a peer leader and to feel included in the STEM community, and so may influence each of the above-mentioned factors that are associated with STEM persistence. Additionally, since URM students tend to have difficulty identifying with STEM and since URM faculty are even more underrepresented among peers than URM students are among theirs, PLTL may have particular benefits for STEM identity for URM students (NAS, 2011).

In summary, because PLTL requires active learning, offers role models, and encourages group interactions, it appears to satisfy what the PCAST (2012) deems necessary to increase student persistence in STEM. Moreover, offering PLTL in an introductory course could be an effective intervention at a pivotal point when many students are known to drop out of STEM majors. We predict that PLTL will influence student recruitment into and retention in STEM for students overall, but we also predict that there will be particular benefits for members of URM groups who tend to drop out of STEM majors at higher-than-average rates and may have more trouble identifying with STEM during lecture-based courses (Brown, Henderson, Gray, Donovan, Sullivan, Patterson, & Waggstaff, 2015; Brown, Reveles, & Kelly, 2005).

Methods

Peer-led Team Learning was offered during the second semester of the Introductory Biology sequence at a large, private university in the American northeast during the Spring of 2011. Data on students who were enrolled in BIO 123 this semester were collected during December of 2014, including declared ethnicities and any officially and unofficially declared majors throughout their academic careers.

We compared students who participated in PLTL versus those who did not, noting that opting to participate in PLTL or not was shown statistically to be unrelated to prior achievement. We considered a STEM major to be any major listed by the National Science Foundation Classification of Instructional Programs for STEM Disciplines (2010). Students were eligible to be “recruited” into STEM only if they did not declare a STEM major upon matriculation to the university and were eligible to be “retained” in STEM only if they ever declared a STEM major. Students were considered “recruited” into STEM if they first declared a STEM major after matriculation. We considered students to have “retained” in STEM if they had remained in a STEM major or had graduated with a degree in a STEM field at the time of data collection—three and a half years after the students completed introductory biology.

Chi-square tests of independence were utilized to examine whether any gaps in STEM recruitment and retention rates existed between URM and non-URM students in the absence of PLTL, whether any differences in these rates were evident if the students participated in the PLTL model, and whether there were any significant improvements in these rates for URM or non-URM students when the students participated in the PLTL model.

Results

Recruitment

Table 5 shows the frequencies of URM students, students who engaged in PLTL, and students who were recruited into/retained in STEM majors. Among the students who did not engage in PLTL, URM students were significantly less likely to be recruited into STEM fields than non-URM students (x^2 = 5.415, df = 1, N = 168, p = .020). Among the students who engaged in PLTL, no significant differences in STEM recruitment rates between groups were observed (x^2 = 1.293, df = 1, N = 92, p = .256). There were no significant differences in recruitment rates between URM students who did and did not engage in PLTL (x^2 = 2.126, df = 1, N = 69, p = .145) or non-URM students who did and did not engage in PLTL (x^2 = .895, df = 1, N = 191, p = .344).

Retention

Among the students who did not engage in PLTL, URM students were significantly less likely to retain in STEM fields than non-URM students (x^2 = 6.324, df = 1, N = 95, p = .012). Among the students who engaged in PLTL, no significant differences in STEM retention rates between groups were observed (x^2 = .135, df = 1, N = 53, p = .713) (Figure 2). Additionally, URM students who engaged in PLTL were significantly more likely to retain in STEM majors than those who did not (x^2 = 6.472, df = 1, N = 32, p = .011), while no statistically significant difference in retention rates was observed between non-URM students who did and did not participate in PLTL (x^2 = 3.451, df = 1, N = 116, p = .063). Chi-square analyses also revealed that high-achieving students—those who received a grade above the median grade—were significantly more likely to retain in STEM majors than low-achieving students (x^2 = 5.862, df = 1, N = 161, p = .015).

Discussion

The results indicate that URM students were significantly less likely to be recruited into or to retain in STEM majors as compared to non-URM students in the absence of PLTL. However, if the students participated in PLTL, no differences in STEM recruitment or retention rates were observed between URM and non-URM students. While there was a significant improvement in STEM retention rates for URM students who participated in PLTL, there was no significant improvement in STEM recruitment rates for these same students.

As a pedagogical approach that demands active learning on behalf of the students, PLTL provides them with a means of making meaning of the course material on their own terms through social interaction with peers. This is associated with better retention of course material and grades in the course (Blake, 2001; Tien et al., 2002). After implementing active learning strategies in a human physiology course, Wilke found that improvements in self-efficacy were associated with increases in course grades for students enrolled in the active learning components of the course (2003). Moreover, URM students have typically earned lower grades than non-URM students in STEM courses (Hunter and Bartee, 2003), and PLTL has been demonstrated to improve grades more for URM students than for non-URM students (Snyder, Sloane, Dunk, & Wiles, 2016). If self-efficacy is tied to student achievement in STEM, student achievement in STEM is associated with student persistence in STEM (as discussed by PCAST), and

PLTL increases grades preferentially for URM students in STEM courses, then differences in self-efficacy between URM and non-URM groups may be able to explain the particular benefit of PLTL on URM STEM retention. Future research should attempt to directly measure the effects of PLTL on self-efficacy in association with these other variables to test this hypothesis.

Identification with STEM may also be able to explain why PLTL has particular benefits for retention of members of URM groups. It has been well-documented that URM students struggle with identification with STEM, and that this is often a reason that they leave STEM fields (Hurtado et al., 2010). Additionally, African-American students who attend Historically Black Colleges and Universities (HBCUs) are far more likely to major in STEM than those at majority institutions (Brown et al., 2015). The PCAST report (2012) indicates that role models are necessary for STEM persistence, and the PLTL model offers role models to students, in the form of peer leaders, who are close to them in age, experience, and identity. In particular, peer leaders are thought to be effective as workshop facilitators and role models because they are considered closer to the students' "zones of proximal development" and also speak and think more similarly to the students than a typical Teaching Assistant or professor would (Tien et al., 2002).

There are several limitations of the studies presented in Chapters 2 and 3 that warrant consideration. For students to participate in PLTL, they must attend weekly workshops in addition to the lecture, meaning that they are required to spend more time working on course content. Even though the PLTL workshop materials were made available to the students who did not participate in the model, without having required that the non-PLTL students spend the same amount of time working on course content, it cannot be ruled out that the extra time spent working on the content could be responsible for the differences observed. Additionally, while we attempted to control for selection bias by testing for prior differences in achievement between those who did and did not opt to participate in PLTL, we cannot rule out that the students who opted to participate in PLTL had higher levels of motivation to achieve and persist in STEM than those who did not. Students were awarded extra credit for participating in the model, but this was not included in the grades reported here.

While we are committed to determining which aspects of PLTL may be responsible for the increased STEM retention we have seen among our students, we are no less committed to continuing our use of PLTL in introductory biology if only for the demonstrated benefits toward achievement we have measured among them (Snyder et al., 2016) as well as self-reported attitudes and feelings of confidence we have seen among our peer-leaders. For non-URM students, the PLTL experience at least does no harm in affecting rates of retention in STEM, but for URM students, it appears to make a very significant difference.

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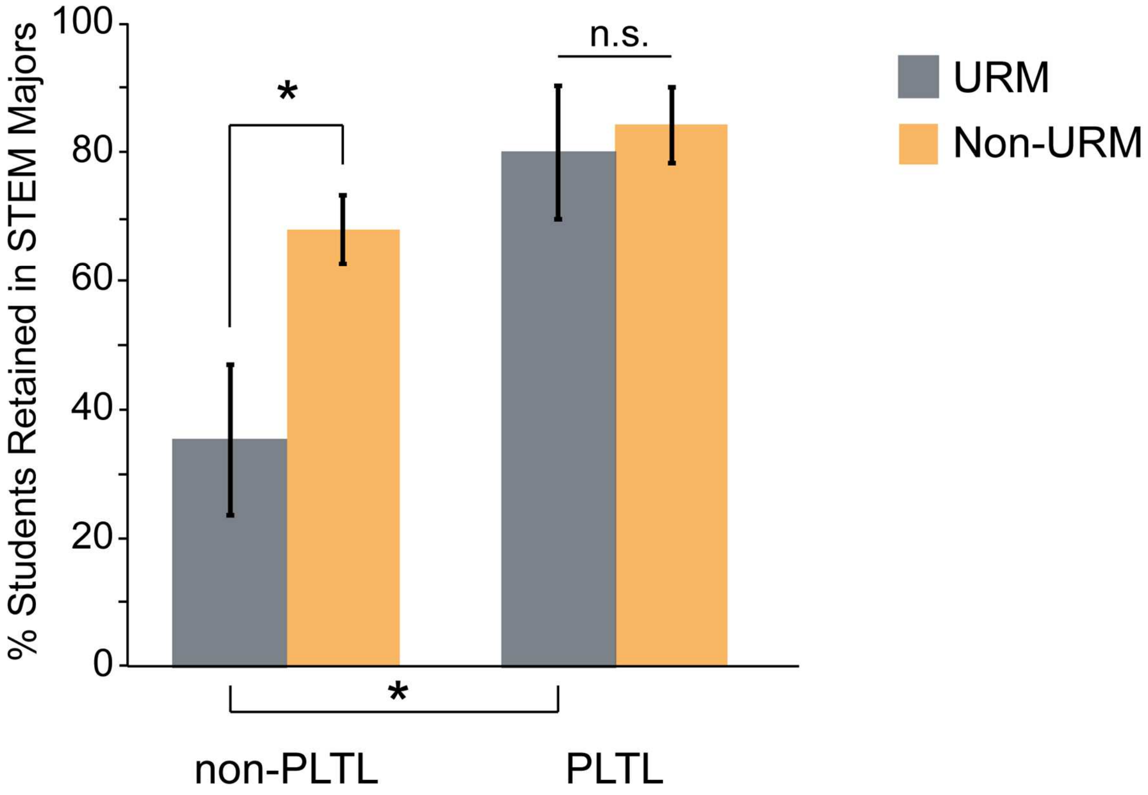
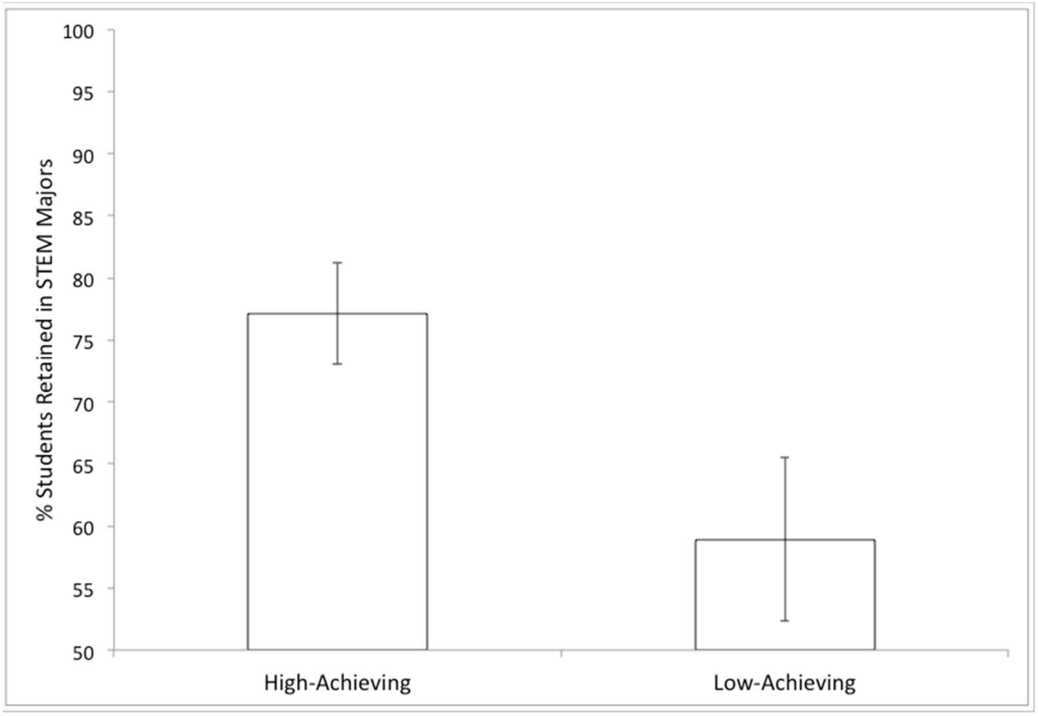
Figure 3: Retention in STEM majors for URM and non-URM students with and without PLTL



Percent of students retained in STEM majors. Values represent percent +/- standard error. Chi-square analyses reveal a significant gap between URM and non-URM students (p = .012) when these students do not participate in PLTL, though no difference in retention rates were observed when students participated in PLTL (p = 0.713).

Figure 4: Retention in STEM majors for High- and Low-Achieving Students

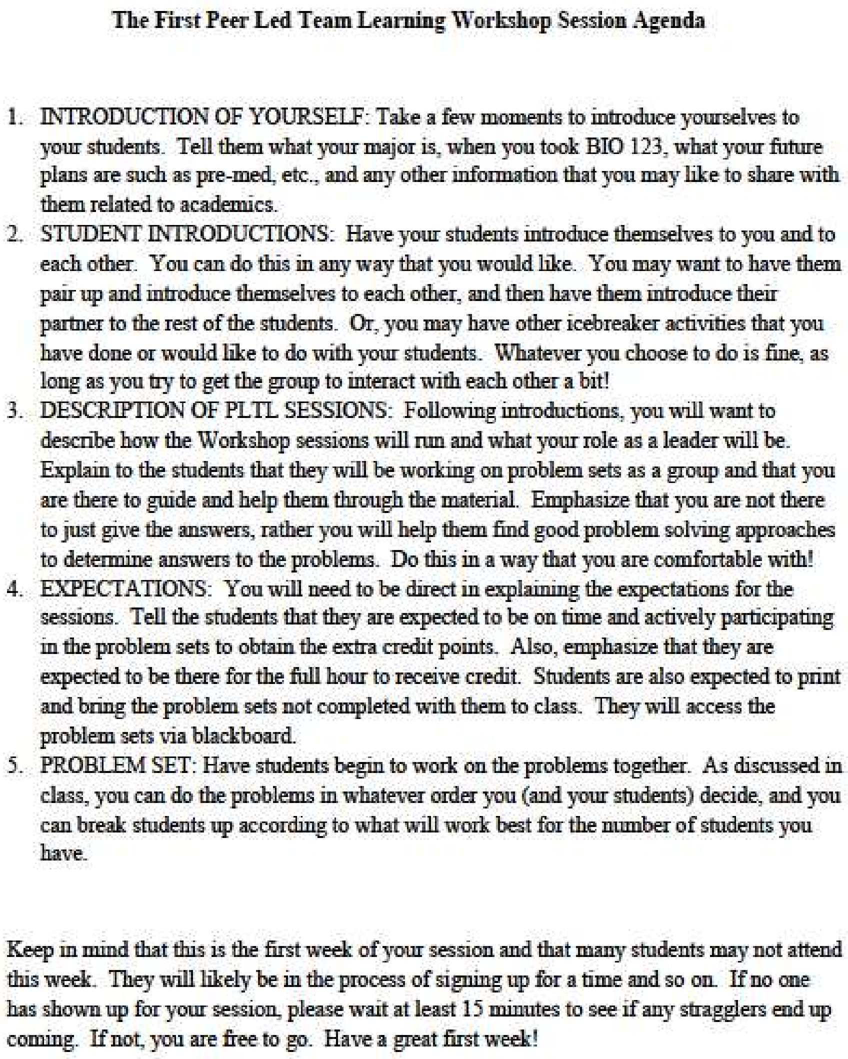


Percent of students retained in STEM majors. Values represent percent +/- standard error. Chi-square analyses reveal a significant difference in retention rates between high- and low-achieving students (p = .015).

Table 5: Frequencies of URM students, students who participated in PLTL, students who were recruited into STEM majors, and students who were retained in STEM majors

	URM	PLTL	Recruited into STEM	Retained in STEM
Yes	88	125	84	114
No	242	233	197	47
Missing	28	0	77	197

Appendix A: First Workshop Agenda



The First Peer Led Team Learning Workshop Session Agenda

1. INTRODUCTION OF YOURSELF: Take a few moments to introduce yourselves to your students. Tell them what your major is, when you took BIO 123, what your future plans are such as pre-med, etc., and any other information that you may like to share with them related to academics.
2. STUDENT INTRODUCTIONS: Have your students introduce themselves to you and to each other. You can do this in any way that you would like. You may want to have them pair up and introduce themselves to each other, and then have them introduce their partner to the rest of the students. Or, you may have other icebreaker activities that you have done or would like to do with your students. Whatever you choose to do is fine, as long as you try to get the group to interact with each other a bit!
3. DESCRIPTION OF PLTL SESSIONS: Following introductions, you will want to describe how the Workshop sessions will run and what your role as a leader will be. Explain to the students that they will be working on problem sets as a group and that you are there to guide and help them through the material. Emphasize that you are not there to just give the answers, rather you will help them find good problem solving approaches to determine answers to the problems. Do this in a way that you are comfortable with!
4. EXPECTATIONS: You will need to be direct in explaining the expectations for the sessions. Tell the students that they are expected to be on time and actively participating in the problem sets to obtain the extra credit points. Also, emphasize that they are expected to be there for the full hour to receive credit. Students are also expected to print and bring the problem sets not completed with them to class. They will access the problem sets via blackboard.
5. PROBLEM SET: Have students begin to work on the problems together. As discussed in class, you can do the problems in whatever order you (and your students) decide, and you can break students up according to what will work best for the number of students you have.

Keep in mind that this is the first week of your session and that many students may not attend this week. They will likely be in the process of signing up for a time and so on. If no one has shown up for your session, please wait at least 15 minutes to see if any stragglers end up coming. If not, you are free to go. Have a great first week!

Appendix B: Raw Data Used to Compute Recruitment and Retention Significance

URM, 1=yes 2=no	PLTL, 1=yes 2=no	Recruited into STEM Major, 1=yes 2=no	Retained in STEM Major, 1=yes 2=no
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