Cyber Peer Led Team Learning (cPLTL) Supports Marginalized Groups, Including Women, in Science, Technology, Engineering, and Mathematics (STEM)

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Abstract: Peer Led Team Learning (PLTL) is an active learning model that is particularly effective for improving the academic achievement and retention of students who have been marginalized in Science, Technology, Engineering, and Mathematics (STEM), such as women, and members of underrepresented minority groups. Cyber Peer Led Team Learning (cPLTL) is a recently developed variation of PLTL that has been transitioned from a face-to-face environment to a synchronous online setting. Studies have found that PLTL and cPLTL students earned comparable educational outcomes in terms of standardized final exam scores and final course grades. Given the benefits of PLTL for marginalized students and the similarities of cPLTL to PLTL, we were interested in understanding the impact that cPLTL had on marginalized groups, including women, in an introductory biology course at a large, research-intensive institution. We found evidence that participating in cPLTL improves the retention of marginalized groups in STEM, and that student perceptions of cPLTL are generally high, especially for women. Participating in cPLTL may have several additional benefits, such as increased motivation, feelings of belonging, comfort in asking questions, and understanding of course content.

Keywords: Peer led Team Learning, cyber Peer Led Team Learning, achievement, retention, perceptions, women, first-generation college student, BHA student, STEM, introductory biology, online learning.

Introduction

For over a decade, major professional organizations have called to reform traditional Science, Technology, Engineering, and Mathematics (STEM) education by using more active learning pedagogies (AAAS, 2011; NCR, 2012). These calls were based on a large and growing body of evidence that has repeatedly confirmed that active learning is a more effective and equitable teaching method than the traditional lecture, regardless of discipline, class size, or course level (Freeman et al., 2014; Theobald et al., 2020).

Among various active learning strategies, Peer Led Team Learning (PLTL; Gosser et al., 1996) is a well-studied instructional model that is often implemented within the context of a large-enrollment gateway course. During a PLTL workshop, groups of six to eight students work collaboratively towards solving a prescribed problem set related to the conceptual content of a course they are taking together. These groups are guided by a peer leader who succeeded in the course during a previous semester by earning a final grade of A or B, and thus was recruited to be a peer leader. Their role is to facilitate teamwork, discussion, and problem solving within the group; not to lecture or tutor the group. The students meet with the same group and peer leader every week to build a sense of community and to develop as a team.

The positive effects PLTL has on undergraduate students has been well documented in a variety of contexts (Snyder et al., 2016; Wilson & Varma-Nelson, 2016). Several studies reported that PLTL students experienced higher academic achievement and improved retention in STEM courses than non-PLTL students (Wilson & Varma-Nelson, 2016). In fact, PLTL is particularly effective for improving the academic achievement and retention of groups of students who have historically been marginalized in STEM (Sloane et al., 2021; Snyder et al., 2016). For example, several studies have shown that women who participate in PLTL achieve higher course grades; lower attrition rates; and lower frequencies of "D", "F", or withdrawal (DFW) grades than women who do not participate in the program (Drane et al., 2014; Horwitz & Rodger, 2009; Preszler, 2009; Quitadamo et al., 2009).

Student perceptions of the benefits of PLTL tend to be positive as well. Students have reported that they perceived the PLTL workshop to improve their content understanding, problem solving skills, critical thinking skills, self-efficacy, and sense of belonging within a course (Wilson & Varma-Nelson, 2016; Wilton et al., 2019). Additionally, students have reported that participating in the PLTL workshops reduced their course-related anxiety (Wilson & Varma-Nelson, 2016).

Cyber Peer Led Team Learning (cPLTL) is a newer and comparatively under-researched variation of PLTL in which student workshops are conducted in a synchronous online setting rather than an in-person context (Mauser et al., 2011). cPLTL was initially developed to provide active learning opportunities to a wider, more diverse student body by creating more flexible scheduling and attendance options. Studies have found that PLTL and cPLTL students earned comparable educational outcomes in terms of standardized final exam scores and final course grades (Mauser et al., 2011; Smith et al., 2014). One study found that students who participated in the PLTL workshop tended to report more positive perceptions of their workshop experiences than cPLTL students, however perceptions of both programs were very positive (Smith et al., 2014).

Further studies demonstrating that cPLTL is effective at improving students' academic achievement and retention across different campuses, disciplines, and student populations are needed to support wider adoption of the program. Special attention should be given to determining the impact of cPLTL for students from marginalized groups because these groups are subjected to programmatic barriers. Programmatic barriers, such as competitive rather than collaborative gateway courses, can make it difficult for marginalized students to succeed in STEM because students must reach a certain level of achievement to pass through the barrier and move on to the next level.

Here, we investigate the effects of cPLTL on marginalized groups at a large, private, research-intensive (Carnegie R1 designation) university in the Northeastern United States, with a special focus on the program's impacts for women. This study aims to address the following questions:

(1) Is participation in cPLTL associated with higher achievement/retention among particular groups of students, including women, in the context of a large-enrollment introductory biology course?

(2) What perceptions do women hold with regards to their cPLTL experience?

Given the previously shown benefits for marginalized students in traditional PLTL programs and given the many similarities of cPLTL to traditional PLTL, we expected that participation in cPLTL would be associated with higher achievement/retention among women, and that students would generally have positive perceptions of cPLTL.

Methods

Setting and Participants

Our study institution has a well-established PLTL program associated with its introductory biology course, which serves mostly freshman and is open to STEM and non-STEM majors (Sloane et al., 2021; Snyder et al., 2015; Snyder et al., 2016; Winterton et al., 2020). During the Fall 2020 semester, the introductory biology course and its associated PLTL program were transitioned to an online format due to constraints imposed by the COVID-19 pandemic. Unlike other cPLTL studies, we were not able to have a PLTL comparison group because of the circumstances. Therefore, we do not attempt to evaluate whether cPLTL results in comparable student outcomes as PLTL, rather we explore the impact of the cPLTL program individually.

Student demographic information is summarized in Table 1. This information came from institutional data, so we are not able to determine if any students identified beyond the binary with regard to gender. Six hundred and fifteen students (33.1% identifying as men: 66.9% identifying as women) enrolled in introductory biology, of whom 145 (20.7% identifying as men: 79.3% identifying as women) enrolled in the cPLTL program. There were four students for whom gender data was not available. A larger proportion of women opted in to cPLTL than what was represented in the whole class, showing that women preferentially chose to participate in cPLTL, X^2 (1, N=611) = 13.1472, p = 0.0003.

Table 1. Percent of students of each demographic group enrolled in introductory biology and in cPLTL.

Demographic Group	Course (n=615)	cPLTL (n=145)
Gender Identity		
*Woman**	66.9	79.3
*Man**	33.1	20.7
Race/Ethnicity		
BHA	26.8	24.5
Non-BHA	73.2	75.5
Generation		
First-generation college student	23.9	22.4
Non-first-generation college student	76.1	77.6

* Indicates significant differences between proportion of students enrolled in cPLTL vs. the whole course.

Within the course, 26.8% of students identified as Black or African American, Hispanic or Latino, or American Indians or Alaska Natives (BHA). First generation college students made up 23.9% of students in the course. There does not appear to have been a selection bias for BHA students (X^2 (1, N=601) = 0.4998, p = 0.4796) or first-generation college students (X^2 (1, N=586) = 0.2382, p = 0.6255), as similar proportions enrolled into cPLTL as was represented in the entire course. Race/ethnicity data was missing for 14 students, and parental education information was missing for 29 students.

Implementation

Recruitment for participation in cPLTL took place during class time. Students were shown the results of prior studies (Snyder et al., 2015; Snyder et al., 2016) to highlight the benefits of the PLTL pedagogy. All students had equal opportunity to opt in to the cPLTL program at the beginning of the semester, and no student groups were encouraged to participate more than others.

There were 36 cPLTL groups, each consisting of 5-8 students. Eleven sessions were offered throughout the semester that lasted 50 minutes each. cPLTL sessions occurred outside of regular class time and attendance was encouraged but not mandatory. At the end of the semester, students received a small amount of extra credit for each PLTL session they attended. Unlike other cPLTL studies, we did not provide students with microphones/headsets, webcams, or document cameras (Mauser et al., 2011; Smith et al., 2014; Wilson & Varma-Nelson, 2021). Peer leaders participated in weekly training sessions where they reviewed course content and pedagogical practices. They received course credit as compensation for being a peer leader.

Data Collection and Analysis

Student course grades, withdrawal status, and demographic data were provided by the course instructors and the Office of Institutional Research. While studies reporting on DFW rates often construe this as a measure of achievement, the W in DFW, which stands for "withdrawal", is also related to retention in the course. Thus, achievement is difficult in some cases to disassociate from retention.

The introductory biology course at our study institution may act as a programmatic barrier because students must earn a C+ or better in the course to declare biology as their major, and/or to meet prerequisite requirements for upper-division courses. Therefore, we decided to focus on the proportion of students earning less than C+ or withdrawing from the course (%CDFW) as a critical measure of achievement and/or retention. Students who achieved a C+ or better in the course were considered to have successfully navigated programmatic barriers, while students who earned a C or less were considered to still have "barriers remaining". A Chi-squared test was conducted to determine if there were significant differences between cPLTL and non-cPLTL groups in this regard.

Our institution provides optional individual and group tutoring sessions for students in the study course through its Center for Learning and Student Success (CLASS). Data regarding the number of tutoring sessions attended by each student in the course was collected from CLASS so that we could consider the data in light of this potentially confounding variable. Only students who participated in three or fewer of the weekly CLASS tutoring sessions were included in statistical analyses. Of these 595 students, 394 (66.2%) were women, 158 (26.6%) were BHA students, 136 (22.9%) were first-generation college students, and 137 (23.0%) participated in cPLTL.

To explore perceptions of our cPLTL program, students were invited to participate in an online post-course survey. Students were recruited through the course Blackboard site and were awarded a small amount of extra credit for participating. The survey consisted of 15 statements that students responded to using a 7-point Likert scale (1 = strongly disagree, 7 = strongly agree), a question asking students if they would recommend cPLTL to a friend, and an open-ended question for respondents to share any additional details about their cPLTL experience. The percentage of students who somewhat agreed, agreed, or strongly agreed with each statement was summed to determine the percent of students who agreed with each statement. Conversely, the percent of students who somewhat disagreed, disagreed, or strongly disagreed with each statement was summed to determine the percent of students who disagreed with each statement. A Chi-squared test was conducted to determine if there were statistically significant differences in the rate of agreement between men and women, BHA and non-BHA students, and first-generation and non-first-generation college students.

Results

Comparison to Previous Semesters

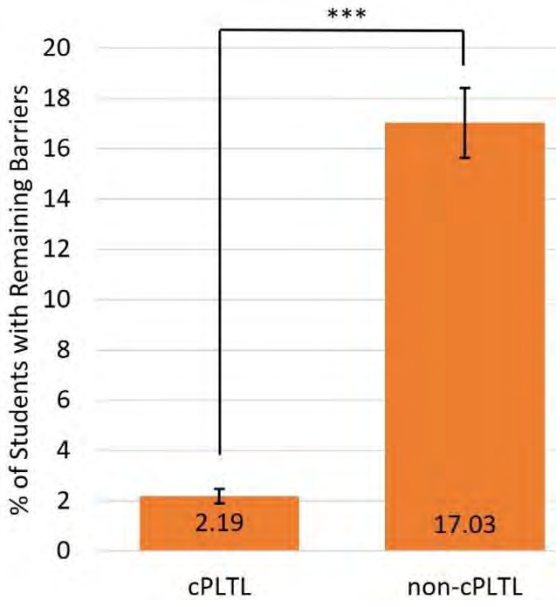
A chi-square test indicated that there was no significant difference in the proportion of students earning CDFW in the introductory biology course between the 2020 and 2019 iterations (X^2 (1, N=1065) = 0.8481, p = 0.3571). For students who participated in PLTL in 2019 or cPLTL in 2020, there was no significant difference in the proportion of students who earned CDFW (X^2 (1, N = 368) = 0.0234, p = 0.8785).

Academic Achievement/Retention

Participating in cPLTL was associated with a smaller proportion of students being left with remaining barriers, X^2 (1, N= 595) = 19.7501, p < 0.0001 (Figure 1). For non-cPLTL students, 17.03% (78/458) were left with remaining barriers, as compared to only to 2.19% (3/137) of cPLTL students.

This trend held true when looking specifically at women (X^2 (1, N= 349) = 12.7748, p = 0.0004), BHA students (X^2 (1, N= 158) = 6.8680, p = 0.0088), and first-generation college students (X^2 (1, N= 136) = 6.5083, p = 0.0107; Table 2). For women, 14.39% (41/285) of non-cPLTL students were left with remaining programmatic barriers, as compared to only 1.83% (2/109) of cPLTL students. For BHA students, 22.58% (28/124) of non-cPLTL students were left with programmatic barriers remaining, as compared to only 2.94% (1/34) of cPLTL students. Similarly, 28.57% (30/105) of first-generation college students who did not participate in cPLTL were left with remaining programmatic barriers, as compared to only 6.45% (2/31) of cPLTL students.

Figure 1: Percentage of students with remaining barriers in introductory biology. Bars represent standard error of percent.



*** Indicates significance of chi-square test at p < 0.0001.

Perceptions

Three-quarters (104/137, or 75.91%) of cPLTL students completed the post-course survey and overall, responses were positive. For the most part, agreement rates for each statement were around 75% while disagreement rates for most statements were around 10% or less (Table 3). About 83% of respondents agreed they were satisfied with their overall cPLTL experience (Table 3; Figure 2), and about 76% of respondents reported that they would recommend online PLTL to a friend (Figure 3).

The statements with the lowest rate of agreement ("Participating in online Peer Led Team Learning helped me form relationships with other students in the course" and "Participating in online Peer Led Team Learning helped me improve my self-confidence") were still rather positive, with 64% agreement (Table 3; Figure 4; Figure 5). Statements with the highest level of agreement were "Participating in online Peer Led Team Learning helped me learn the course material" with almost 88% agreement, "I am comfortable asking questions during online Peer Led Team Learning workshops" with 86.83% agreement, and "My Peer Leader was able to provide supportive feedback during the online Peer Led Team Learning workshops" with 85.27% agreement (Table 3; Figure 4; Figure 6).

Table 2. Percent of cPLTL and non-cPLTL students with remaining barriers in introductory biology.

	Non-cPLTL (n=458)			cPLTL (n=137)			
Student group	n	% with remaining barriers		n	% with remaining barriers		p
Women (n=394)	41	14.39		2	1.83		0.0004
BHA (n=158)	28	22.58		1	2.94		0.0088
First-gen (n=136)	30	28.57		2	6.45		0.0107

Table 3. Percentage of respondents (N=104) who agree, neither agree nor disagree, or disagree with each statement.

Statement	% Disagree	% Neither	% Agree
I am satisfied with my overall online Peer Led Team Learning Experience.	8.53	8.53	82.95
I am comfortable asking questions during online Peer Led Team Learning workshops.	7.75	5.43	86.83
My Peer Leader was able to provide supportive feedback during the online Peer Led Team Learning workshops.	5.43	9.30	85.27
Participating in online Peer Led Team Learning helped me learn the course material.	3.89	8.53	87.59
Participating in online Peer Led Team Learning improved my ability to work as a part of a team.	10.09	17.83	72.09
Participating in online Peer Led Team Learning improved my ability to communicate effectively.	10.80	18.60	71.31
Participating in online Peer Led Team Learning improved my ability to solve problems.	9.30	16.28	74.42
Participating in online Peer Led Team Learning improved my motivation to learn general biology.	11.63	13.95	74.42
Participating In online Peer Led Team Learning improved my performance in general biology.	6.99	15.50	77.52
Participating in online Peer Led Team Learning improved my self-confidence.	17.83	18.60	63.56
Participating in online Peer Led Team Learning helped me form relationships with other students in the course.	17.83	17.83	64.35
Participating in online Peer Led Team Learning made me feel included in the course.	9.31	19.38	71.31
Participating in online Peer Led Team learning made the course material more interesting.	12.40	18.60	68.99

Figure 2. Student responses to the statement "I am satisfied with my overall online Peer Led Tam Learning experience."

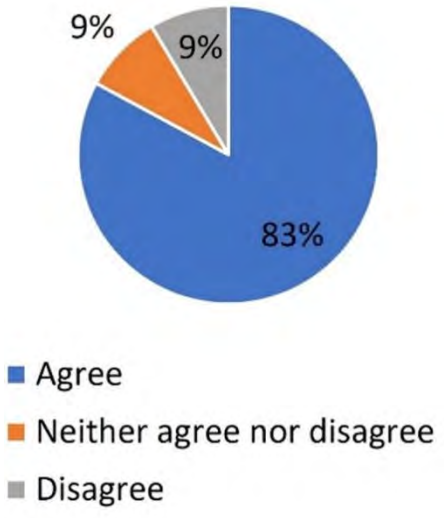


Figure 3. Student responses to the question "Would you recommend online Peer Led Team Learning to a friend?"

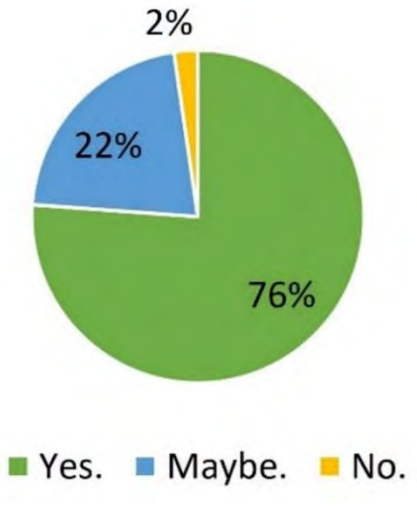


Figure 4. Responses to the statements "Participating in online Peer Led Team Learning improved my self-confidence," (left) and "I am comfortable asking questions during online Peer Led Team learning workshops," (right).

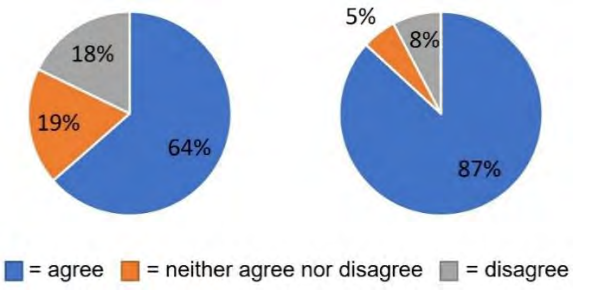


Figure 5. Responses to the statements "Participating in online Peer Led Team Learning helped me form relationships with other students in the course," (left) and "Participating in online Peer Led Tam Learning made me feel included in the course," (right)

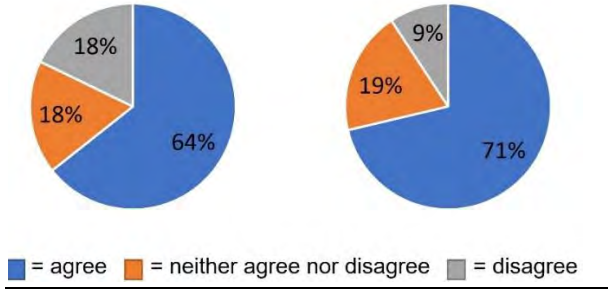
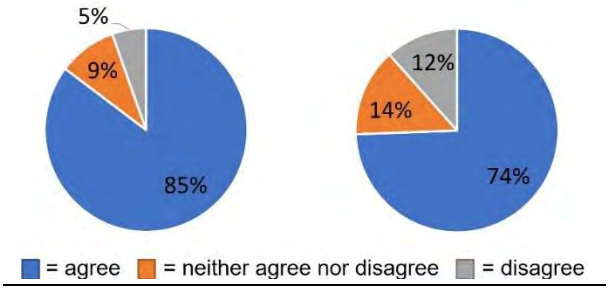
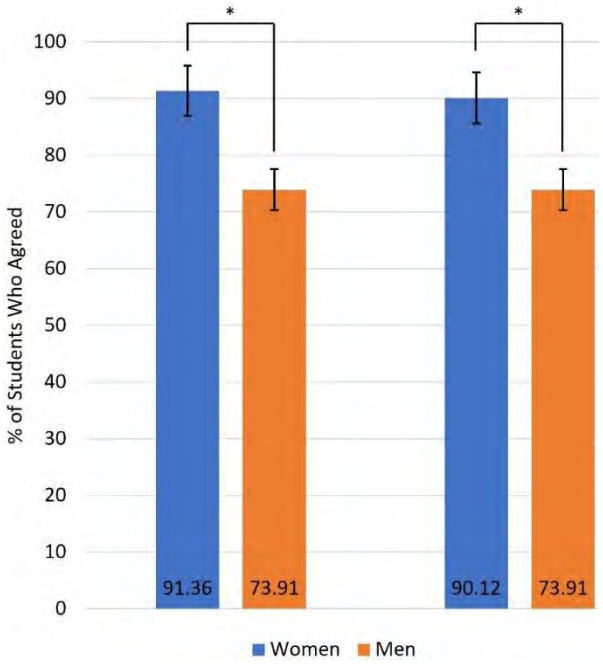


Figure 6. Responses to the statements "My Peer Leader was able to provide supportive feedback during the online Peer Led Team Learning workshops," (left) and "Participating in online Peer Led Team Learning improved my motivation to learn general biology," (right).



A chi-squared test indicated that women and men differed significantly in their agreement rate for two of the perception statements (Figure 7). Women agreed more often than men that participating in cPLTL helped them engage with the course material (91.36%; X^2 (1, N = 104) = 4.9843, p = 0.0444), and improved their understanding of key course concepts (90.12%; X^2 (1, N = 104) = 4.0408, p = 0.0363). There were no significant differences in the agreement rate of BHA and non-BHA students, or first-generation and non-first generation college students.

Figure 7. Percentage of men (n=23) and women (n=81) who agreed with the statements "Participating in online Peer Led Team Learning helped me engage with the course material.", (left) and "Participating in online Peer Led Team Learning improved my understanding of key course concepts ." ,(right).



* Indicates significance of chi-squared tests at p < 0.05

Discussion

Academic Achievement/Retention

Overall, students performed well in the introductory biology course during the Fall 2020 semester. Without cPLTL, 17.03% of students would not have had the option to declare a biology major and would not have met prerequisite requirements for upper-division courses (Figure 1). With cPLTL, this number was reduced to only 2.19%.

We saw similar trends when looking specifically at women, BHA students, and first-generation college students. Out of 109 women who participated in the program, only two were left with remaining barriers, and these women still earned passing grades of C (Table 2). This means that women who participated in cPLTL were 12% more likely to successfully navigate programmatic barriers than those who did not participate, and that 98% (107/109) of women who participated in cPLTL had achievement sufficient to declare a biology major and move on to upper-division courses.

Perceptions

The online format of our introductory biology course and cPLTL program may make it difficult to form relationships with other students in the course. Peer Leaders have observed that students who participate in cPLTL appear to be comfortable working together and spend time talking about topics unrelated to course content, however, the relationships they build may not translate into social connections outside of the cPLTL workshop (Smith et al., 2014). Given the difficulties students may face when forming relationships in an online setting, we are pleased that in the current study, two thirds (64.35%) of the respondents agreed that participating in cPLTL helped them form relationships

with other students in the course and almost three fourths (71.31%) of the respondents agreed that participating in online PLTL made them feel included in the course (Table 3; Figure 5). These findings suggest that participating in cPLTL can have a positive impact on students' feelings of belonging and ability to form relationships within an online gateway course.

Another concern we had was that the online format may reduce students' motivation to show up and participate in class. Motivation is important because it is a critical predictor of many educational outcomes such as academic achievement and retention (Lazowski & Hulleman, 2016; Robbins et al., 2004). Three fourths (76.54%) of our respondents agreed that participating in cPLTL improved their motivation (Table 3; Figure 6). This sentiment is echoed in the responses to the open-ended questions, as one woman wrote:

> It took a toll on my motivation not being able to go to a classroom and meet my professors in person [during the pandemic]. I feel like if I had [c]PLTL for other of my classes I would've done better in them and my motivation wouldn't have been so lost.

These findings suggest that increased motivation as a result of participating in cPLTL may be a mechanism by which cPLTL could improve educational outcomes.

Studies on gender-differences in the classroom have shown that men tend to be more comfortable asking questions and to ask more questions than women in academic settings (Daly et al., 1994; Hinsley et al., 2017). This could be because question asking is linked to self-efficacy (Daly et al., 1994). Women may experience lower self-efficacy than men, and thus have lower confidence in their ability to pose an appropriate question (Daly et al., 1994; Good, 1987; McMullin & Cairney, 2004). In the current study, about two thirds (63.56%) of the respondents agreed that participating in cPLTL improved their self-confidence, and nearly nine out of ten (86.83%) agreed that they were comfortable asking questions during cPLTL workshops (Table 3; Figure 4). These findings suggest that participating in cPLTL could facilitate women using their voices and vocally participating in an academic setting. Responses to the open-ended question reflected this idea, as one woman shared, "Overall I found [cPLTL] to be very helpful as it was a much more comfortable environment to ask questions and get help."

In addition to hoping that the cPLTL workshops would be a comfortable place to ask questions, we hoped that the peer leaders would be able to provide supportive feedback to participating students. Receiving supportive feedback can help students form a strong science identity (Park et al., 2018). Identifying with science is important for students in STEM majors, as studies have shown that students with a strong science identity tend to persist in their STEM major longer and experience greater interest in scientific careers than those who do have a weak science identity (Chang et al., 2011; Perez et al., 2014). However, forming a strong science identity can be difficult for women for a variety of reasons. Competitive, rather than collaborative, gateway courses can sometimes lead to women feeling less competent in their scientific knowledge or pose challenges related to stereotype threat (Ahlqvist et al., 2013; Seymour & Hewitt, 1997). In the current study, nearly nine out of ten (85.27%) respondents agreed that their Peer Leader was able to provide supportive feedback during the cPLTL workshops (Table 3; Figure 6), which suggests that cPLTL may help women identify with science.

The reason we point out that men and women differ in some of their cPLTL perceptions is not necessarily to draw comparisons between them, rather to emphasize the extent to which women perceived cPLTL to have had a positive impact on their experience in an online gateway course. As shown in Figure 7, nine out of ten women who completed the post-course survey agreed that participating in cPLTL helped them engage with the course material (91.36%) and improve their understanding of key course concepts (90.12%). One woman shared, "…the best benefit of [cPLTL] is that you really learn the material since it is reinforced during the one-hour session through engaging activities and questions." Together, these findings highlight the extent to which women feel that participating in cPLTL benefits their learning experience.

Conclusion

We contribute valuable insights and implications into teaching and learning science at the collegiate level by exploring the benefits that cPLTL has to offer for students who have historically been marginalized in STEM. Our study is unique in that we are the first to document cPLTL in an introductory biology course. We found evidence that participating in cPLTL improved achievement/retention among women, BHA students, and first-generation college students. Student perceptions of cPLTL were generally high in our study population, especially for women. Additionally, in our population of students, women preferentially participated in cPLTL. However, we did not see this selection bias for BHA students or first-generation college students. Future work should focus on these groups and understanding how we can encourage them to opt in because cPLTL helps them, too.

In addition to improving educational outcomes of students, participating in cPLTL may have several additional benefits such as increased motivation, feelings of belonging, comfort in asking questions, and support in forming a strong science identity. Future work should use an intersectionality approach to explore the unique lived experiences of students, and to better understand how their personal identities interact with the cPLTL environment to provide these various benefits.

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