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| Research Article

# Peer leader perspectives from a PLTL implementation in a Hispanic-serving institution

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**ABSTRACT** Peer-Led Team Learning (PLTL) is a pedagogical approach that has been shown to benefit all students, especially underrepresented minority students and peer leaders in Science, Technology, Engineering, and Mathematics (STEM) disciplines. In this work, we present results from our study of the impact of PLTL on our peer leaders from a controlled implementation in general biology, general chemistry, and statistics courses at a Hispanic-serving, minority-serving institution. More specifically, we have measured our PLTL program's impact on our peer leaders' skill development, engagement with the subject material, and sense of belonging as peer leaders. Weekly peer leader reflections analyzed using the Dreyfus model exhibited a consistent set of skills, while those analyzed using the Pazos model revealed a consistent type of student-peer leader interactions, allowing for peer leaders to be assigned to specific levels in the hierarchy of each of the models. Analysis of eight skill-based Likert-scale questions on the SALG survey showed an overall positive shift at the highest level. Independent of the skill or interaction level of the peer leader, we observed several instances of peer leaders acknowledging development in their communication skills, sincere attempts at creating an engaging classroom, and a deep investment in their student's success. Peer leaders also reported improvements in understanding of the subjects they were teaching, wanting to persevere and solve problems independently, and feeling passionate about helping other students.

**KEYWORDS** peer-led team learning, minority serving institution, STEM , perspectives, HSI

Peer-Led Team Learning (PLTL) has been shown to improve performance in various courses for all students, especially underrepresented minority students in Science, Technology, Engineering, and Mathematics (STEM) disciplines (1–7). An additional benefit of PLTL is the benefit to the peer leaders themselves. Several studies have reported higher grades for peer leaders (8–10), higher graduation rates (11), motivated peer leaders declaring a major in the subject (8) or taking more courses (9) in that discipline, access to new methods of learning (12), acquiring facilitation and leadership skills (13–15), and an appreciation and growing interest in being a teacher (8, 16, 17).

PLTL is a pedagogical approach in which students enrolled in a lecture course participate in a 50–120-min attached workshop that meets within or outside of lecture time in small groups of about 6–10 students with a peer leader. The peer leaders are students who have taken and completed the course successfully. Since the peer leaders are not necessarily content experts and are closer in content knowledge and skill level to the students enrolled in the class than the instructor, their interaction proves valuable in ways that are not always accessible to the instructor (1, 2). Upon joining the program, they are enrolled in a mandatory credit-bearing training course that covers techniques for leading small group discussions, understanding group dynamics,

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*We dedicate this manuscript to the memory of Prof. Janet Liou-Mark*

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and motivational and learning theory (18). They also write weekly reflections on their implementation of PLTL in workshops as well as conduct a research project related to PLTL. During weekly workshops with students, peer leaders utilize various group-based pedagogical approaches to lead the students in group discussions that help students answer questions posed in a worksheet developed or approved by the faculty instructor (1, 19, 20). Studies have examined the impact of PLTL on the peer leaders themselves, and scales have been developed and adapted to measure such impacts (20).

Given the benefits for all students, especially underrepresented students in STEM disciplines, we implemented PLTL at a Hispanic-serving, minority-serving institution. PLTL was implemented at our institution to improve the D/F/W rates (the percentage of grades of D or F or W students withdrawing from the course) of students enrolled in critical gateway courses in biology, chemistry, and psychology. The impact of our PLTL program on improving the D/F/W rates of the students will be reported elsewhere. In this work, we present the data and corresponding analysis that highlight the impacts of our PLTL program on our peer leaders. We analyzed the weekly peer-leader reflections and self-reported gains from items on the Student Assessment of Learning Gains (SALG) surveys to assess the progress made by our peer leaders. Weekly reflections submitted by the peer leaders in their e-portfolio were analyzed using two models that allowed for assessing their development as peer leaders [Dreyfus model (21, 22)] and their problem-solving and interaction with their students [Pazos model (23)]. The peer-leader responses from the SALG surveys also allowed us to determine if similar gains to those reported in the literature, such as in skill development, sense of belonging, and engagement with the subject material, would be seen in our peer leaders. These positive impacts on our peer leaders, the majority (>50%) of whom were from traditionally underrepresented backgrounds in STEM disciplines, allow them to develop better strategies for their own learning, a caring attitude toward their students, and an appreciation of the challenges in teaching and learning. When the peer leaders are supported appropriately by the program organizers and by the faculty they work with, the PLTL program can have a significant positive impact on them.

## METHODS

### Study design

#### *Implementation*

PLTL was implemented in the following courses: General Biology I lecture (BIOL160), General Chemistry I lecture (CHEM160), and Statistics for Social and Behavioral Science lecture (PSYN370). BIOL160 and CHEM160 are gateway courses to the biology major, the health science major, and other STEM programs. PSYN370 is a core statistics course in the psychology major and a prerequisite for students who aspire to various graduate programs in psychology and the health sciences. All these courses exhibited low retention and consistently high D/F/W rates, particularly among our minority and underrepresented students.

Our research design was based on that conducted by Drane et al. (24). According to this design, approximately half of the course sections were assigned as PLTL after they were listed in the course catalog (i.e., students did not know they were registering for a PLTL section). The faculty were then notified that their section was PLTL with a workshop session scheduled before or after the lecture period. PLTL sections had 3–4 peer leaders (a ratio of 1 peer leader to 6–8 students) assigned to lead workshops. The peer leaders were provided with standard workshop materials approved by lecture instructors for use in the workshops. Alternatively, instructors could choose to provide their own materials. The control sections in general biology and general chemistry had a recitation for the same duration either before or after the lecture period. The recitation sessions were led by 1–2 students (a ratio of 1 recitation leader to 15–30 students) who received a single day of introductory orientation to recitation prior to the start of the semester. The recitation leaders were also expected to meet at least once a week with

their faculty to discuss their plans for the recitation. The materials used by the recitation leaders came from the instructors. Unlike the biology and chemistry courses, the PLTL sections in the Statistics for Social and Behavioral Sciences course had a PLTL workshop in the last 50 min of the instructor's lecture period (2 h 50 min total lecture period) (2), whereas the control sections did not have a corresponding workshop, and the entire class period was taught by the lecture instructor. PLTL peer leaders and the recitation leaders were recruited from among those students who have successfully completed BIOL160, CHEM160, or PSYN 370 with a grade of B or higher. The peer leaders were assigned sections they would be peer-leading for based on whether their schedule allowed them to peer-lead a particular workshop section.

### *Peer leader training*

A training program for the peer leaders was based on the standard PLTL curriculum at the City University of New York. During their first semester as peer leaders, they received training in two stages: a single 6-h long training session that introduced them to PLTL, the context of the institution, an explanation of the research study, a presentation of the data collected thus far, and examples of classroom scenarios and how to address them. The course instructors were also invited to attend this training so that they could meet and engage with their peer leaders. Faculty were also invited to attend the mandatory semester-long credit-bearing (1-credit) course on PLTL. A sample syllabus is shown in the supplemental information (see SI: Appendix 1). The course in the first 6 weeks included discussing the theories and background of cooperative teaching and learning, including topics such as Tuckman's Team Development Model (25); Effective Communication and Pair Problem Solving; Vygotsky's Zone of Proximal Development (26); Deci and Ryan's Self-Determination Theory (27); and Equity and Diversity (28). The PLTL training course was structured predominantly as a guided discussion.

In weeks 7 to 13 of the training course, the peer leaders designed an individual research project on topics related to PLTL and its implementation. During weeks 7 to 13, the peer leaders were encouraged to meet with the instructor of the credit-bearing course to discuss and streamline their project ideas. Depending on the peer leader's choice of topic, they had the option either to pursue a project in which they collected data from their students using a survey that they had created or a theoretical analysis of a PLTL-related topic. At the end of the semester, they presented their research poster to their fellow peer leaders in a symposium setting. Research posters covered a variety of topics, including motivation, scaffolding, diversity, problem-solving, and peer leader involvement (see SI: Appendix 2). The peer leaders also recorded weekly reflections either as an ePortfolio on Digication or in discussion forums on blackboard.

Peer leaders were required to meet with their assigned course (BIOL 160, CHEM 160, or PSYN 370) instructor for 1 h/week in advance of the classroom workshop to review the content of the lecture course and to familiarize themselves with workshop materials. These weekly meetings also allowed peer leaders to discuss the previous workshop with faculty. Peer leaders had access to the faculty member's materials on blackboard. The recitation instructors received 1-day training for 2–3 h on the details of the recitation program. The recitation leaders were also expected to meet with the instructors at least once a week to get guidance on the content to be covered in the recitation for that week. The peer leaders and recitation instructors were paid for 6 h/week/course of work according to the wage standards at the institution.

### *Peer leader assessment*

Peer leaders enrolled in the training seminar course were assessed on their weekly ePortfolio or discussion board reflections, mid-semester focus groups, their research posters, and the SALG (29). The self-assessment SALG survey was administered twice, once at the start and once at the end of the semester. SALG asks students to assess and report on their own learning and on the degree to which specific aspects of the course have contributed to that learning (29).

## Methods of data analysis

### *Analysis of peer leader reflections*

Analysis of the peer leader reflections was performed similarly to the method described by Glover et al. (20), who developed a novel scale by combining aspects of the Pazos model (23) and the Dreyfus model (21, 22). The Pazos model classifies group learning into two key aspects: group interaction style and problem-solving approach. The group interaction style was further divided into individual-oriented and collaborative, while the problem-solving approach was divided into simple and elaborate. A detailed description of the categories can be found in reference (23). Dreyfus's model (21, 22), on the other hand, provides five stages for assessing the progress in a skill-training endeavor. The five stages they proposed were novice, competence, proficiency, expertise, and mastery. Glover et al. (20) used a modified Dreyfus model to assign peer leaders to the following stages of development: novice, abbreviated as "(N)," transitioning, "(T)," advanced beginner, "(AB)," or competent, "(C)." The (N) label indicates that the leader showed evidence of beginning at a Dreyfus-Novice stage and remaining in that stage throughout their journal entries.

We adapted these scales to fit the reflections using an inductive approach. Our coding schemes reflect the characteristics found in our data sample that matched the Pazos model categories of interaction and problem-solving styles and the stages of development described in the Dreyfus model. Although the Dreyfus model can show growth in peer leaders from reflecting on classroom procedures to applying and reflecting on learning theories, given the level of detail in the reflections submitted by our peer leaders and the number of submissions, we decided to focus on the consistency of the practices used by the peer leaders to assign them to the various skill levels. A detailed description of each level with the characteristics we incorporated at each level for both models is included in the supplemental information (see SI: Appendix 4). Since the Pazos model does not allow for the description of transitioning behavior, we analyzed the peer leader reflections based on consistency in the types of interactions between the students and the peer leaders. Due to the differences in the models, we analyzed the reflections based on these two models and reported on them separately. To increase the reliability of the analysis, the peer leader reflections were analyzed collectively by three different instructors of the PLTL program. Each student's reflections were discussed between the three instructors, and a consensus was reached about the competency level and the problem-solving approach of each peer leader.

### *Analysis of peer leader feedback from SALG surveys*

Eight key skill-based survey questions, with Likert scale responses on the SALG survey, were analyzed to gage the gains made by the peer leaders during their first semester as peer leaders.

### *Peer leader feedback from focus groups*

The peer leaders also participated in in-person, mid-semester focus groups to provide feedback on their experiences in the PLTL program. Feedback was collected in the absence of the instructors and students so that they could freely express their opinions about the program.

### *Safety issues*

The project was reviewed by the Mercy College IRB and found to be exempt.

# RESULTS

## Competency analysis of peer leaders

From Spring 2018 to Spring 2020, there were 58 peer leaders (56 undergraduate and 2 graduate). Of the 58 peer leaders, 53 (91.38%) were female, and the 5 remaining were

male (8.62%). These peer leaders participated in the PLTL program for a minimum of one semester, and of them, 46 wrote weekly reflections based on a set of prompts. Ten peer leaders (10 females) were excluded from the 46 during the data analysis due to their recording insufficient (two or fewer) reflections, leaving us with reflections from a total of 36 peer leaders [31 females (86%), 5 males (14%)]. The prompt for their reflections is shown in SI: Appendix 3. The demographics and grade level of the peer leaders are shown in Fig. 1. Since many of the peer leaders did not report their first-generation status, no analysis was done on this variable.

The competence of a subset of peer leaders ($N = 36$) was analyzed using the modified Dreyfus model (see Fig. 2A) and the Pazos model (see Fig. 2B). A minimum of three reflections was required for peer leaders to be included in this analysis. Ideally, the best peer leaders are expected to be competent (the highest level in Dreyfus) and use guided discussion (the highest level in Pazos) as their problem-solving style (see SI: Appendix 4 for a rubric used for analysis based on these two models). When comparing the two analyses, there appeared to be a similar distribution between the two scales. For example, at the two extremes, 38.89% of peer leaders were novices, and 44.44% used simple instruction, while 8.33% of peer leaders were competent, and 13.89% used guided instruction. However, only 9 peer leaders in the novice (total = 14) and simple instruction (total = 16) categories and 1 peer leader in the competent (total = 3) and guided instruction (total = 5) categories were the same students. Sample reflections from peer leaders reflecting the highest level of competence in each of these models are shown in Table 1. Sample reflections for all the levels of competence based on both of these models are shown in the Supplementary information (see SI: Appendix 5).

The Dreyfus model allows for observing evolution in peer-leader skill level when appropriate prompts for peer-leader reflections and enough detailed reflections are available at various time points during a course. The Pazos model focuses more on understanding the types of student-peer leader interactions. The prompts for reflection given to our peer leaders in this study are shown in SI Appendix 3. They were required to submit a minimum of six reflections throughout the semester. While this did not allow us to follow the complete evolution in the skill level of our peer leaders, we were able to observe the most consistent practices and types of interactions of our peer leaders over time. One key aspect that was emphasized in the initial 6-h training and in the seminar class that took place throughout the semester was the focus on not providing the answers to the students directly. In the peer-leader reflections, in-class discussions,

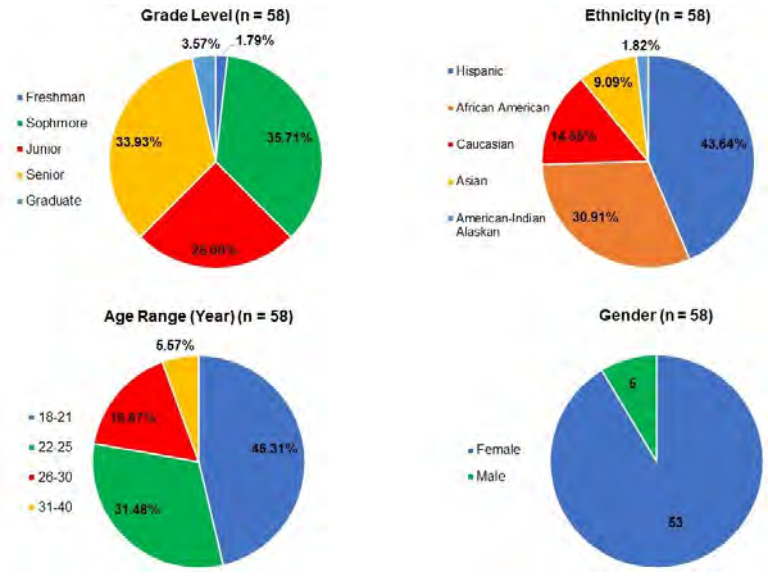


**FIG 1** Demographic information of all recruited peer leaders. We present the data that follow for peer leaders that contributed data to either the SALG or the reflections that were analyzed.

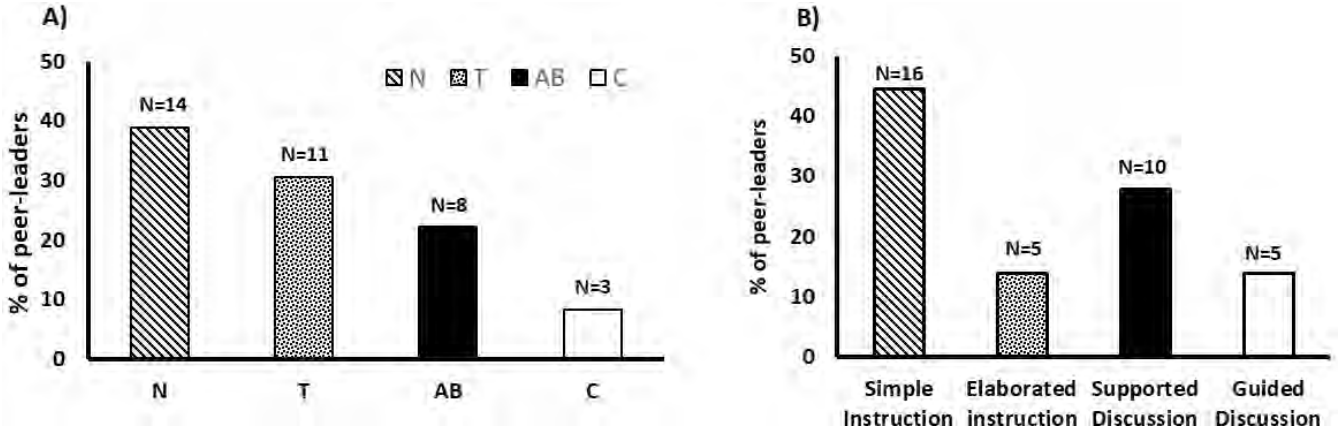


**FIG 2** Categorization of peer leader competency based on the (A) Dreyfus model of skill acquisition for all peer leaders (*n* = 36) and (B) Pazos model of group interaction style for all peer leaders (*n* = 36). The results for 36 of the 47 peer leaders were included in the analysis presented here as they had generated sufficient reflections (greater than 2) during the 1-semester seminar course. In the Dreyfus model (see Fig. 2A), the following stages of development were used: (N), (T), (AB), or (C). Please see SI Appendix 4 for a detailed description of these models. The N values shown at the top of the bars indicate the number of peer leaders that were in each category out of the total of 36 peer leaders. These values were used to obtain the percentages of peer leaders in each category shown in the bar graph.

and private conversations, it was very clear that the peer leaders took this message to heart and did their very best not to give direct answers. This resulted in peer leaders engaging in the approach of asking leading questions and providing the necessary tools to the students, encouraging them to find their own answers. This was easily identifiable when the peer-leader reflections were descriptive and detailed enough. When the details were lacking and/or when the reflections were very peer leader-centric and/or procedure-centric, the peer leaders were assigned to a lower level on both the Dreyfus and Pazos scales.

## Analysis of pre- and post-peer leader responses from SALG surveys

The SALG survey (29) was administered to the peer leaders at the beginning (pre-semester) and end of their first semester (post-semester) as peer leaders. The pre-semester and post-semester SALG surveys provide insights into the evolution of gains in certain key skills, but as the surveys were anonymous, it was not possible to track the evolution of individual peer leaders. Upon completion of the survey, responses from eight selected skill-based survey items important in the context of PLTL were analyzed to infer changes because of training and serving as a peer leader. Overall, the bar graphs in Fig. 3 shows shifts toward higher self-reported gains, which are reflected in bar 4 (a great deal) for all survey items. Items 3a) understanding of how to implement pedagogical techniques, 3b) understanding how to communicate effectively in a workshop setting, and 3f) applying what I learn in class to other situations showed the largest gains from pre to post (~25%–30%) in bar 4 (4 a great deal). The next highest gains of ~15% (bar graph 4) were observed in items 3e) connecting key ideas I learn in my class with other knowledge, 3g) using systematic reasoning in my approach to problems, and 3h) using a critical approach to analyzing data. The lowest gains of ~5% (bar graph 4) were observed in items 3c) developing logical arguments and 3d) confident that I can be a peer leader. In all survey items, it is interesting to note that there is also a decrease that is observed between pre- and post-semester surveys, especially in bar graphs 1—not at all/just a little, 2—somewhat, and 3—a lot, which to some extent could be attributed to an increase in the percentage of peer leaders in bar graph 4 (a great deal), among other reasons.

**TABLE 1** Sample peer leader reflections at the highest level of peer leader competence based on the analysis performed using the Dreyfus model and modified Pazos model

| Peer leader competence | Example peer leader comments from each competency level |
|---|---|
| Modified Dreyfus model | |
| Competent (C) | *"This week's PLTL session came after the first exam for my students. The feedback I received from them regarding their exam was mixed. Some of the students did not feel adequately prepared for the exam due to either a lack of knowledge about the material or an inability to relate the exam questions to the material that they studied. Others felt that they could have been better prepared, and the rest felt that the exam was fair. One resounding comment was that the students felt that having more hands-on experience during the PLTL sessions would help them retain material for the next exam. The week before the exam, Professor Tutnauer did want us to have the students complete a worksheet full of material from a section of the course that would not be tested on the upcoming exam, and some of the students felt that a review would have been more beneficial. One thing that I really do have to praise my students over is that at least twice they would ask to go over more problems once the worksheets have been completed. On more than one occasion, we have stayed a little later so that they are all able to have a turn at answering questions. The techniques that I have used on my students and will continue to use that seem to work the best include us going over a problem as a group with me prompting them and asking 'why?' questions, breaking them up into small groups of 2 and having them solve problems as a team, and doing round-robin answering of the problems. My students have definitely become more comfortable working together and correcting each other and asking their own 'why?' questions." (Week 9, student 1*) |
| | *"During the workshop this week, my group retained themselves (i.e. did not leave), and pulled together right away to start working on the worksheet given. This was much to my delight! Our group has begun to be the only group willing to work on PLTL worksheets and discuss items collectively. We kept our group together, as well as the option of reading through the material, and picking out challenging activities. I decided to ask my students what they want to do beyond graduating college, what are they working towards? I took time this week to discuss them, as the worksheet was rather easy and they had ample time left. I'm glad I did! I learned that one of the students wants to go to medical school, has actually already been accepted to Einstein Medical school, but is here at Mercy because his grandmother fell ill, is in Montefiore Hospital, and he is the only one who can care for her. He declined entering medical school, is a senior here and is retaking this class because Mercy didn't let his biology transfer (CRAZY!!)—I was reminded of the bureaucracy and business-money minded side of colleges. Why are they making him retake this? Nonetheless, two others are going into physical therapy, one undecided, one into Physician Assistant and one into Vet Tech. They were happy to share information and it was a great session! I Instagram'd about my excitement to go PLTL this week. ;-)" (Week 4, student 2)* |
| Pazos model | |
| Guided discussion (GD) | *"Generally, the atmosphere in the workshop was good. To be specific, for the multiple-choice questions, I tried to vote on the answers, and then they gave me their thoughts and reasons why they chose and how they thought. I urged participants toward a decision, as I learned from the seminar. They could make their own examples whenever I asked, and helped each other whenever one student fell behind. Also, they had a lot of questions, and they tried to find the answers by themselves through discussion. I found that half of my group were highly motivated, but still, verbal members tended to dominate." (Week 2)* |

(*Continued on next page*)

**TABLE 1** Sample peer leader reflections at the highest level of peer leader competence based on the analysis performed using the Dreyfus model and modified Pazos model (*Continued*)

| Peer leader competence | Example peer leader comments from each competency level |
|---|---|
| | *"In this workshop, we finished the module 13, which is about one sample t-test. For question number one, all they needed to do was look at the table and find the corresponding number. Some students had troubles to find the answers, so they asked me how to find that, instead giving explanation, I asked to other students so that they can help each other. For the question two and three, I asked them which formulas should be used, and what numbers mean in given questions." (Week 9, same student as above)* |
| | *"Today's workshop went exceptionally well. As always, I wasn't sure what I should expect going into the workshop because I did not know how the students received the new material they learned. I was pleasantly surprised to hear at arrival that they had done really well on their exams and can confidently say that perhaps for the first time all semester, I was able to truly witness the students come together to work with one another successfully in working through the Modules provided by PLTL. They seemed confident in their knowledge of the material and felt comfortable coming to me with questions on how to work through it. I also was able to feed from their confidence and felt confident in my own ability to lead the peer-led discussion. I was able to help them come to their own conclusions by providing additional examples and further clarification of some of the newly learned concepts and definitions and felt the students left feeling sure in what they know regarding the topic." (week 11, same student as above)* |

### Analysis of peer leader posters

Peer leaders were required to research a topic of their choice related to PLTL in their seminar course. These projects were placed in seven broad categories, as shown in Fig. 4 (also see SI Appendix 2 and 6). Some of the projects/posters focused on the conceptual aspects of the seminar course, whereas many focused on developing surveys to collect relevant data from the students in their workshops on the research topic of the poster.

### Analysis of peer leader academic performance

Of 58 peer leaders, 51, or about 90%, were able to graduate from our institution within 6 years, and of those, 42 graduated within 4 years. Of these 42 students, 19 first-time full-time students graduated within 4 years, while 23 transfer students graduated within 3 years of their transfer to our institution. Two of those peer leaders had also graduated from master's programs or second bachelor's degrees. The peer leaders took an average of 13.55 (SD = 3.00) credits per semester compared to the college-wide average of 11.14 credits. Likewise, peer leaders had a higher average GPA of 3.49 (SD = 1.68) compared to 2.93 for the average undergraduate. Nine out of the 58, or about 16%, continued into master's programs at our institution, and 12 others pursued graduate or professional degrees at other institutions. When comparing Hispanic peer leaders with non-Hispanic leaders, we found no significant differences based on credits taken per semester and average GPA. In general, the peer leaders who were part of the PLTL program were those who were performing well academically. Although it was not clear to what extent the PLTL program helped in their future career success, it is possible that the PLTL program provided an avenue for a cohort of academically motivated students to share ideas and find support and motivation in their fellow peer leaders.

## DISCUSSION

In the current work, we present the results and analysis from one of the first reported controlled trials of PLTL in a Hispanic-serving institution. We report on the effect of PLTL on the peer leaders themselves, who are the central cogs in the interactions between the

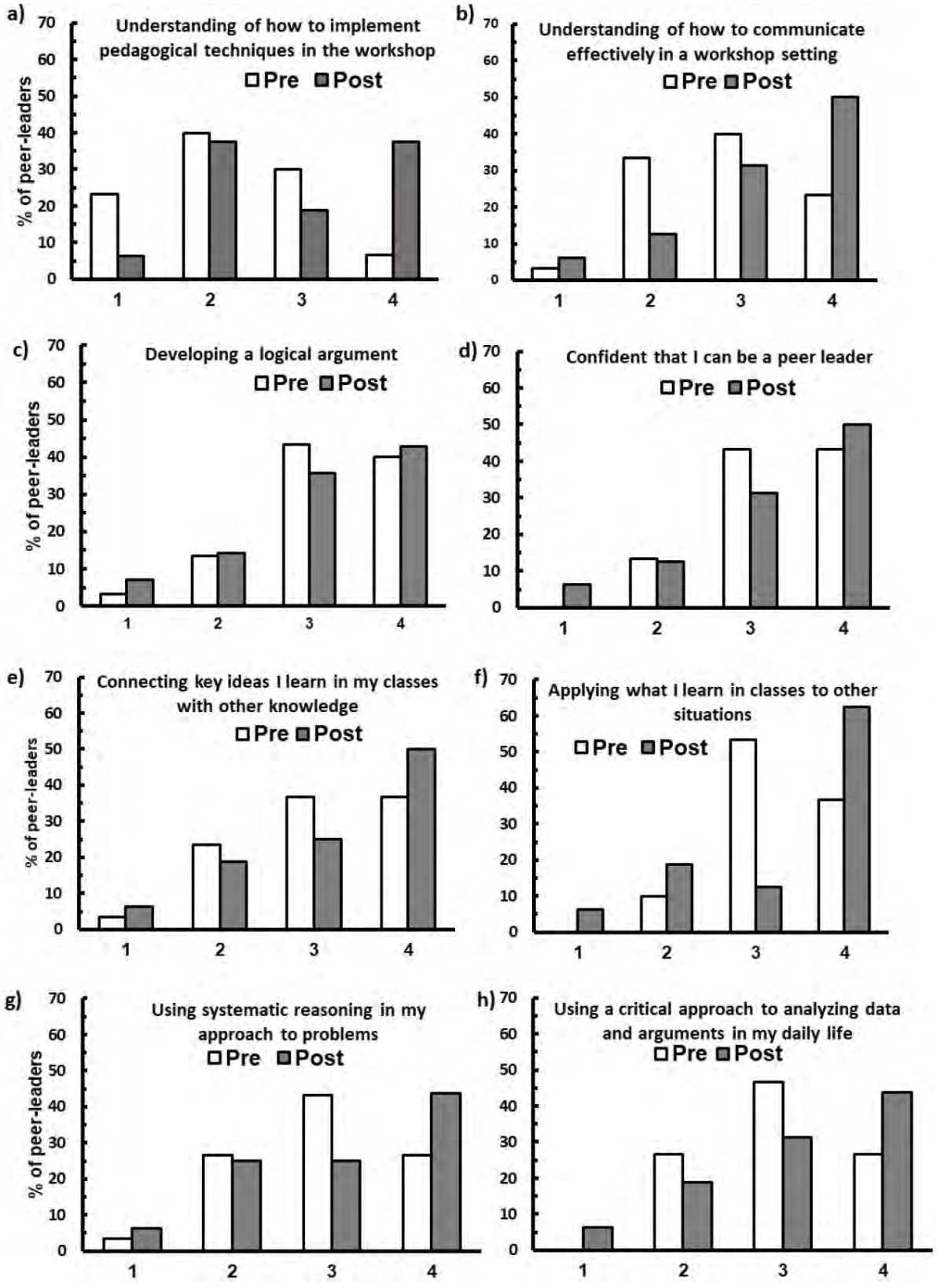


**FIG 3** Analysis of pre- and post-responses for select items from the SALG surveys showing a shift toward higher gains. 1—not at all/just a little, 2—somewhat, 3—a lot, 4—a great deal.

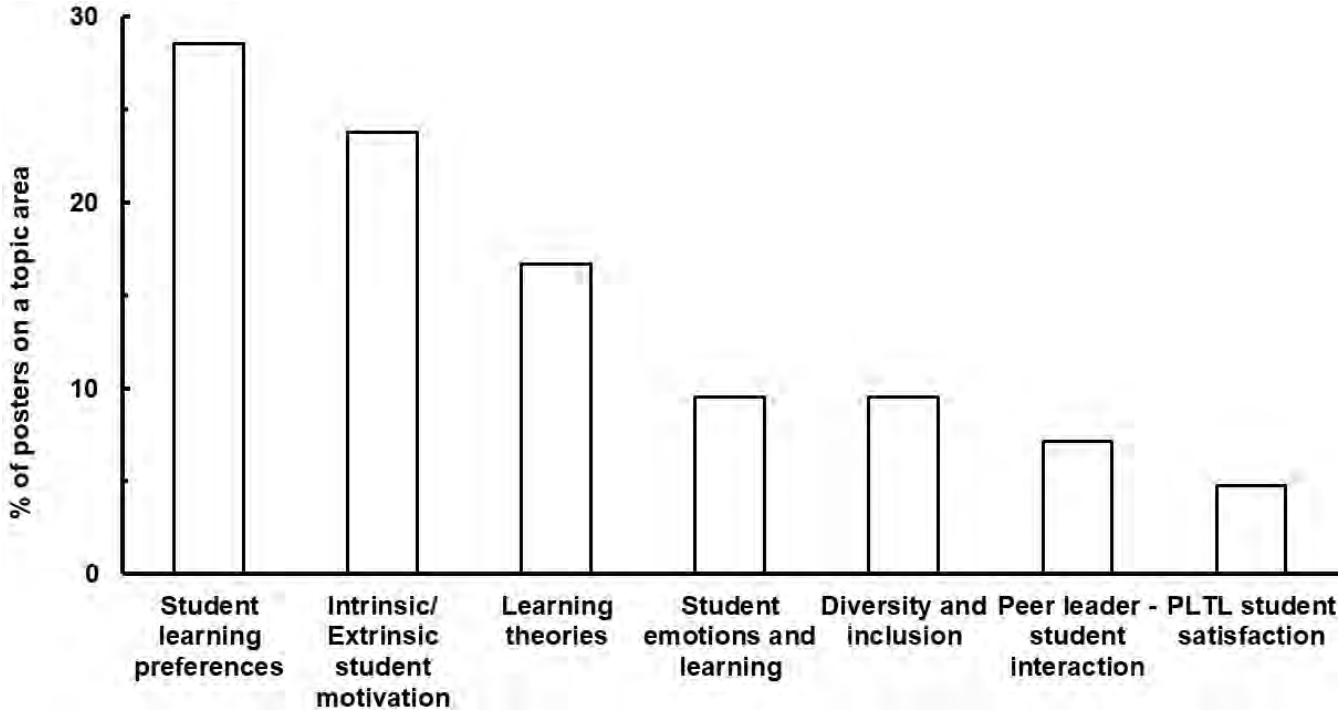


**FIG 4** Analysis of topic distribution chosen by the peer leaders for their end-of-the-semester poster presentation.

students taking the course and the faculty teaching the course. It must be noted that there are existing studies reporting on the benefits of PLTL for peer leaders (8, 12, 15, 30–33). Anecdotally, most of our peer leaders reported that their peer-leading experience was positive, and that it benefitted the students overall, as has been reported in a previous study (13). Our peer leaders' reflections and feedback were similar to that reported by Johnson et al. (15) in that they highlighted the transition in attitudes undergone by the peer leaders from being apprehensive about their role and capabilities as peer leaders in the beginning to hitting their stride in the middle and being challenged to motivate the students and encourage them to interact with each other and being totally committed to finding effective teaching techniques to benefit the students. Some peer leaders commented that serving as peer leaders reinforced their content knowledge and helped them prepare for advanced courses as well as graduate and professional schools. At all levels of competency, our peer leaders' reflections showed evidence of constantly working to reflect on, improve, and address three themes: (i) environment, (ii) group dynamics, and (iii) facilitation, which are the focus areas of PLTL (34).

Peer leader reflections were analyzed using two models (20–23) to assess their skill level as peer leaders. Although both models involve scales that delineate the various interaction styles, the Pazos model (23) focuses more explicitly on peer leader problem-solving (interaction) styles with the students as being either instructional or discussion-based. Similar to what has been reported by Brown et al. (35), we also found that when peer leaders use participative dialogue (getting students more involved in the classroom discussion), it results in increased student-to-student interactions and more student participation. Although we did not measure this in a quantitative fashion, we could see several instances of peer leaders using leading questions and encouraging language to get students to participate in answering the questions on the worksheet as a group. Various topics of the training they received made the peer leaders very conscious of encouraging group work rather than using a lecturing style of interaction.

We also saw several instances where the peer leaders extensively used facilitative interactions and provided managerial support, and students displayed extended

discussion that went beyond applying equations in a rote manner and began to develop a deep conceptual understanding (36). Depending on the level of preparation of the students when they arrived at the workshops and on the material being covered, on the one hand, the peer leaders had to step in to re-teach concepts, and on the other hand, on certain topics, the peer leaders were able to engage in more group work (37). The second model used (Dreyfus) identified four different competence levels (see Fig. 2).

Taking the two models together, there appeared to be a reasonable agreement between the novice/competent categories and simple instruction/guided discussion, which implies that novice (N) (38.89%) peer leaders generally tend to use simple instruction (44.44%) as their mode of interaction with the students, whereas competent peer leaders (8.33%) tend to use guided discussion (13.89%) as their pedagogical style. However, only 9 peer leaders in the novice (total = 14) and simple instruction (total = 16) categories and 1 peer leader in the competent (total = 3) and guided instruction (total = 5) categories were the same students. This difference could be attributed to the difference between the two models and how they were applied in our analysis (see SI Appendix 4). A $\chi^2$ test found a significant relationship between peer leaders' Dreyfus and Pazos model scores [$\chi^2 = (16, 57) = 73.141$, $P = <0.001$], particularly due to the correlation between peer leaders who were categorized as novices and those who tended to also be categorized as in the simple instruction category. Additionally, $\chi^2$ tests were conducted to determine if there were significant differences between the categorization of Hispanic and non-Hispanic students for the Dreyfus model or the Pazos model, with neither being statistically significant [Dreyfus $\chi^2$ test: $\chi^2 = (4, 57) = 3.22$, $P = 0.522$; Pazos $\chi^2$ test: $\chi^2 = (4, 57) = 3.078$, $P = 0.545$]. The Dreyfus model focuses more on the peer leader's view of the workshop environment, what they were doing in the classroom, what the students were doing, and the reflections of peer-leader actions on the students. However, the Pazos model focuses explicitly on the levels of interaction between the students and the peer leaders. It is quite possible that the peer leaders may have a high level of interactive style on the Pazos scale but not be reflective about their practices, which is one of the key features on the Dreyfus scale.

Since reflections were collected over just their first semester as peer leaders, a significant percentage of our peer leaders are at the novice/simple instruction level. If reflections were to be collected for multiple semesters, we would expect to see a shift toward a higher level of competence (more reflective on the application of learning theories and on their own role in the workshop and in student learning) and more interactive styles over time. One key concern some of the peer leaders seemed to struggle with was the level of student preparation when the students arrived for the workshops. Peer leaders often found that they needed to re-explain some content that the students were expected to know from the lecture portion of the course. Even though this approach was helpful to the students, it may have put the peer leaders in the novice/simple instruction/elaborate instruction category.

The peer leaders responded to a SALG survey at the beginning and end of every semester. These results are compiled in Fig. 3. When observing the bar graph with the pre (unshaded) and post (shaded) boxes, one can see that there is an increase in gains for each of the survey items in 4—"gained a lot" category. Items 3a) understanding of how to implement pedagogical techniques, 3b) understanding how to communicate effectively in a workshop setting, and 3f) applying what I learn in class to other situations showed the largest gains (~25%–30%). The next highest gains of ~15% were observed in items 3e) connecting key ideas I learn in my class with other knowledge, 3g) using systematic reasoning in my approach to problems, and 3h) using a critical approach to analyzing data. The lowest gains of ~5% were observed in items 3c) developing logical arguments and 3d) confident that I can be a peer leader. However, in 1—"not at all/just a little," 2—"somewhat," and 3—"a lot" categories, the post-survey shows a dip. This could be attributed to an increase in the percentage of peer leaders in bar graph 4 (a great deal). Another reason for this dip in gains could perhaps be due to the Dunning-Kruger effect (38), where peer leaders overestimated their capabilities in a certain area at the

beginning of the task and found it to be more challenging as they progressed. It is also possible that they perhaps started seeing the nuance in a topic as a peer leader, which they did not appreciate before, leading to a feeling of lower confidence toward the end. This dip may also indicate increased metacognition in peer leaders, which they have gained through facilitating and becoming more aware of how much there is to learn in the subject matter (39). It is interesting to note that some of the peer leaders' (50%) self-reported gains were very high in items 3c) developing logical arguments, 3d) confident that I can be a peer leader, and 3e) connecting key ideas I learn in my class with other knowledge in bar graph 4 (4 a great deal), and this did not change significantly toward the end. This could be attributed in part to the initial peer leader training and also to the fact that the peer leaders chosen to PLTL were top students with a high degree of self-confidence and self-efficacy to begin with.

Analysis of non-Likert scale SALG survey questions and peer-leader reflections revealed some key information regarding the experience of peer leaders, and they are shown in Table 2. Although we did not have a pre- and post-semester knowledge test to assess their knowledge in the courses they were peer leading, the SALG responses from the peer leaders indicate that preparing for the workshops to explain various topics to the students did improve their own understanding of the content matter. Several of our peer leaders also felt that being a peer leader increased their own motivation toward learning and perseverance when they were solving difficult problems on their own. The peer leaders' weekly reflections provide insight into the fact that many of them found the experience of being a peer leader in the PLTL program to be gratifying, and that they felt very happy helping the students and seeing them overcome obstacles and succeed.

Peer leaders also completed a research project where they designed projects based on topics related to PLTL. Many of them created survey instruments, to which they requested responses from their own workshop students. These kinds of surveys were considered IRB-exempt. They analyzed these results and presented them in the form of a poster at the end of the semester. The diverse array of topics they chose to research and the percentage of students in each topic area are shown in Fig. 4. Apart from them presenting their topics, it was clear from the passion they exhibited during the presentation that they had developed a deeper appreciation of teaching and learning practices.

An additional outcome we identified from implementing the control study was that we were able to use the feedback we had received from the peer leaders to improve the program over time. Along with modifying the worksheets, the assessments, and the training course, there were two key areas that were specifically identified by the peer leaders that we consider critical for the success of the program. Our implementation revealed a huge variation in faculty interactions with the peer leaders, from how often they met or communicated with the peer leaders to how aware the faculty were of the content covered in the workshops. These interactions (or lack thereof) had a huge impact on how the peer leaders and students experienced PLTL. In addition, according to the PLTL model, the PLTL workshops are expected to last 60–90 min/wk. However, in our implementation of PLTL, the workshop time was limited to 50 min due to restrictions in space and scheduling. Furthermore, it was challenging to add the workshop as a mandatory part of the course, as this increased the in-class course time. Based on the feedback from our peer leaders and students, it was clear that they would have preferred to have longer workshops, giving peer leaders more time to help the students. The time to devote to workshops remains a challenge for our institution owing to space limitations and the scheduling needs of the programs.

## Limitations

Future work should continue to focus on the benefits to peer leadership for peer leaders. While this study provides a start to understanding how the act of teaching peers can have positive benefits, there are several limitations. In this study, we did not collect any data from recitation leaders, so we cannot determine if there are similar benefits for

**TABLE 2** Sample peer leader SALG responses in the post-semester surveys and weekly reflections highlighting some key benefits of PLTL for our peer leaders

| Outcomes | Peer leader survey/reflection responses |
|---|---|
| Increased knowledge of course content<br>Based on the post-semester SALG survey item "Please comment on how leading the workshops helped with understanding the class materials" | *1) You do not know material until you are able to teach it, so very much so.*<br>*2) It forced me to have to do an adequate review of everything I learned from before and then pass the info along to more people.*<br>*3) It helps a lot because biology is a foundation that can be reinforced while doing PLTL.*<br>*4) It does help a lot. When we explain something, for some reason. our brains tend to understand it better and remember it.* |
| Increased motivation and problem solving on their own<br>Based on the post-semester SALG survey item "What did you learn or gain in the peer leader training class that you will carry with you into other classes or other aspects of your life?" | *1) It helped me develop more intrinsic motivations. Also, better studying habits.*<br>*2) Keep working at hard problems and topics. There were many times where students were frustrated with certain topics, but I was able to give them the push they needed so that they felt more confident in the topic.*<br>*3) Learning new techniques and reading the book helped because it gave us ideas of what to do in certain situations and how to go about problems.*<br>*4) I learned how to interact with others and view problems from a different viewpoint.* |
| Discovering a passion to help fellow students and understanding the challenges faced by students<br>Based on the peer leaders' weekly reflections about their workshops | *1) **....** When I'm leading the workshop, I genuinely enjoy it. I like helping students work through concepts and understandings. When they leave our 50 min session feeling more confident in even one concept from the lecture, it's rewarding to wake up and travel to the Bronx for it. :-)*<br>*2) … As I mentioned before, my group is very friendly and supportive of each other where if one of the students has a question, they all chip in, helping them out and figuring out the solution. I think it is very important knowing that none of us were born taught and we all struggle with similar concepts, but the coursework is possible, and I am there to help guide them to the right path and be their "course support."*<br>*3) … intrinsic is the internal gratification, such as the gaining of knowledge or freedom. Extrinsic is external gratification, such as money or a reward. I was able to apply this to class by helping nurture the students' desire to understand the material in order for them to gain the intrinsic reward of knowledge.*<br>*4) Today, one of my students, who usually keeps to herself, actually took the initiative to do one of the more challenging problems and got it right and was able to explain all of the steps to the other students. I was very proud of her and I really do think that having PLTL has been beneficial in helping our students develop confidence in chemistry and confidence in themselves.* |

recitation leaders. It may be important to disentangle if the benefits to peer leaders are from the act of leading as a student alone (where we would expect to see similar benefits and growth for recitation leaders) or if the interactive style and reflective practice of peer leading lead to this growth. There were also different leader-to-student ratios across conditions, and this too could have an impact on peer leader experiences. In the PSYN370 courses, students in PLTL were compared to students in a longer lecture without the extra recitation. In this case, students were missing out on time with their faculty. More investigation is needed into the impact of the loss of lecture time to make way for peer-led workshop sessions. Lastly, we did not have a large enough sample to complete an analysis of peer leaders broken down by ethnicity, which may have an impact on peer leader experiences.

## Conclusion

In this study, we have reported the impact of our PLTL implementation on the peer leaders at a Hispanic-serving, minority-serving institution. While peer leaders reported

relatively high confidence in their skills and abilities at the start of the semester, they reported moderate to large gains in these same skills and abilities at the semester's end. Through the SALG, written reflections, and poster projects, we observed that our peer leaders made modest gains in several areas, such as increased knowledge of course content, increased motivation and problem-solving on their own, discovering a passion to help fellow students, and understanding the challenges faced by both students and faculty. Their written reflections showed that many peer leaders were willing to implement learning theory in their practice as peer leaders. By providing peer leaders with autonomy in their poster projects, peer leaders thoughtfully discussed theory in their own peer-leading practice and how it related to student success. Future research is needed to show the strength of these effects of peer leader training and development on confidence and skill acquisition as peer leaders.

An additional benefit of gathering data on the peer leaders' perspectives is that we were able to leverage their thoughts and ideas to improve the program as we were building it and to take recommendations from them. Peer leaders' feedback and engagement with the program provided helpful suggestions to better implement PLTL. Given our institutional context, we feel that by sharing our data, analysis, and the valuable perspectives of our peer leaders, we will not only add to the literature on PLTL implementations but also help other institutions that are considering PLTL improve the outcomes for their students and peer leaders alike.

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## ADDITIONAL FILES

The following material is available online.

### Supplemental Material

**Supplemental Material (jmbe00075-23-s0001.docx).** Appendices and additional material.

## REFERENCES


1. Tien LT, Roth V, Kampmeier JA. 2002. Implementation of a peer-led team learning instructional approach in an undergraduate organic chemistry course. J Res Sci Teach 39:606–632. https://doi.org/10.1002/tea.10038
2. Lewis SE. 2011. Retention and reform: an evaluation of peer-led team learning. J Chem Educ 88:703–707. https://doi.org/10.1021/ed100689m
3. Born WK, Revelle W, Pinto LH. 2002. Improving biology performance with workshop groups. J Sci Educ Technol 11:347–365. https://doi.org/10.1023/A:1020642318162
4. Hockings SC, DeAngelis KJ, Frey RF. 2008. Peer-led team learning in general chemistry: implementation and evaluation. J Chem Educ 85:990. https://doi.org/10.1021/ed085p990
5. Preszler RW. 2009. Replacing lecture with peer-led workshops improves student learning. CBE Life Sci Educ 8:182–192. https://doi.org/10.1187/cbe.09-01-0002
6. Carmichael MC, St Clair C, Edwards AM, Barrett P, McFerrin H, Davenport I, Awad M, Kundu A, Ireland SK. 2016. Increasing URM undergraduate student success through assessment-driven interventions: a multiyear study using freshman-level general biology as a model system. CBE Life Sci Educ 15:ar38. https://doi.org/10.1187/cbe.16-01-0078
7. Wilson SB, Varma-Nelson P. 2016. Small groups, significant impact: a review of peer-led team learning research with implications for STEM education researchers and faculty. J Chem Educ 93:1686–1702. https://doi.org/10.1021/acs.jchemed.5b00862
8. Tenney A, Houck B. 2004. Learning about leadership: team learning's effect on peer leaders. J Coll Sci Teach 33:25–29.
9. Amaral KE, Vala M. 2009. What teaching teaches: mentoring and the performance gains of mentors. J Chem Educ 86:630. https://doi.org/10.1021/ed086p630
10. Murray JD. 2011. Peer learning and its applications to undergraduate psychology instruction. Promot Stud Engagem 1:166–169.
11. Flores B, Becvar J, Darnell A, Knaust H, Lopez J, Tinajero J. 2010. Implementing peer led team learning, p 15. In Gateway science and mathematics courses for engineering majors. https://doi.org/10.18260/1-2--16650
12. Snyder JJ, Wiles JR. 2015. Peer led team learning in introductory biology: effects on peer leader critical thinking skills. PLoS One 10:e0115084. https://doi.org/10.1371/journal.pone.0115084
13. Gafney L, Varma-Nelson P. 2007. Evaluating peer-led team learning: a study of long-term effects on former workshop peer leaders. J Chem Educ 84:535. https://doi.org/10.1021/ed084p535
14. Hug S, Thiry H, Tedford P. 2011. Learning to love computer science: peer leaders gain teaching skill, communicative ability and content knowledge in the CS classroom. Sigcse11 - Proc 42Nd ACM tech symp comput sci educ. https://doi.org/10.1145/1953163.1953225
15. Johnson E, Robbins B, Loui M. 2015. What do students experience as peer leaders of learning teams? Adv Eng Educ 4:1–22.
16. Stewart B, Amar F, Bruce M. 2007. Challenges and rewards of offering peer led team learning (PLTL) in a large general chemistry course. Austral J Ed Chem 67
17. Tenney A, Houck B. 2003. Peer-led team learning in introductory biology and chemistry courses: a parallel approach. J Math Educ Collab Exp 6:11–20. https://doi.org/10.25891/6PGZ-J157
18. Quitadamo IJ, Brahler CJ, Crouch GJ. 2009. Peer-led team learning: a prospective method for increasing critical thinking in undergraduate science courses. Sci Educ 18:29–39.
19. Woodward AE, Weiner M, Gosser D. 1993. Problem solving workshops in general chemistry. J Chem Educ 70:651. https://doi.org/10.1021/ed070p651.1
20. Glover R, Hammond NB, Smith J, Guerra D. 2018. Assessing peer leader skill acquisition and group dynamics in a first-year calculus course. ij-sotl 12. https://doi.org/10.20429/ijsotl.2018.120110
21. Dreyfus HL, Dreyfus SE. 2004. The ethical implications of the five-stage skill-acquisition model. Bull Sci Technol Soc 24:251–264. https://doi.org/10.1177/0270467604265023
22. Dreyfus SE, Dreyfus HL. 1980. A five-stage model of the mental activities involved in directed skill acquisition. University of California (Berkeley), Operations Research Center, Berkeley.
23. Pazos P, Micari M, Light G. 2010. Developing an instrument to characterize peer-led groups in collaborative learning environments: assessing problem-solving approach and group interaction. Assess Eval High Educ 35:191–208. https://doi.org/10.1080/02602930802691572
24. Drane D, Micari M, Light G. 2014. Students as teachers: effectiveness of a peer-led STEM learning programme over 10 years. Educ Res Eval20:210–230. https://doi.org/10.1080/13803611.2014.895388
25. Bonebright DA. 2010. 40 years of storming: a historical review of Tuckman's model of small group development. Hum Resour Dev Int13:111–120. https://doi.org/10.1080/13678861003589099
26. Shabani K, Khatib M, Ebadi S. 2010. Vygotsky's zone of proximal development: instructional implications and teachers' professional development. Engl Lang Teach 3:237–248. https://doi.org/10.5539/elt.v3n4p237
27. Legault L. 2017. Self-determination theory, p 1–9. In Zeigler-Hill V, TK Shackelford (ed), Encyclopedia of personality and individual differences. Springer International Publishing, Cham. https://doi.org/10.1007/978-3-319-28099-8
28. Vicki R. 2001. Peer-led team learning: a Handbook for team leaders. 1st ed. Prentice Hall, Upper Saddle River, NJ.
29. Seymour E, Wiese D, Hunter A-B, Daffinrud S. 2000. "Creating a better mousetrap: On-line student assessment of their learning gains"National Institute of Science Education, University of Wisconsin-Madison, San Francisco, CA, USA
30. Blake R. 2001. What are the benefits of PLTL for student leaders. Discrete Inq Newsl Progress Peer-Led Team Learn 2:5–6.
31. Cress CM, Astin HS, Zimmerman-Oster K, Burkhardt JC. 2001. Developmental outcomes of college students' involvement in leadership activities. J Coll Stud Dev 42:15–27.
32. Micari M, Streitwieser B, Light G. 2005. Undergraduates leading undergraduates: peer facilitation in a science workshop program. Innov High Educ 30:269–288. https://doi.org/10.1007/s10755-005-8348-y

33. Johnson EC, Loui MC. 2009. Work in progress - how do students benefit as peer leaders of learning teams?, p 1–2. In 2009 39Th IEEE frontiers in education conference. https://doi.org/10.1109/FIE.2009.5350637
34. Szteinberg G, Repice MD, Hendrick C, Meyerink S, Frey RF. 2020. Peer leader reflections on promoting discussion in peer group-learning sessions: reflective and practiced advice through collaborative annual peer-advice books. CBE Life Sci Educ 19:ar2. https://doi.org/10.1187/cbe.19-05-0091
35. Brown PL, Sawyer K, Frey R. 2009. Peer-led team learning in general chemistry: investigating the discourse of peer leaders and students
36. Brown PL, Sawyer K, Frey R. 2009. Investigating peer-leader discourse in peer-led team learning in general chemistry
37. Brown P, Sawyer K, Frey R, Luesse S, Gealy D. 2010. What are they talking about? findings from an analysis of the discourse in peer-led team learning in general chemistry, p 773–777. In Learning in the disciplines: icls 2010 conference proceedings - 9th international conference of the learning sciences
38. Kruger J, Dunning D. 1999. Unskilled and unaware of it: how difficulties in recognizing one's own incompetence lead to inflated self-assessments. J Pers Soc Psychol 77:1121–1134. https://doi.org/10.1037//0022-3514.77.6.1121
39. Powers K, Kelly M, Colby K, Narayanan M, Smyth D. 2019. .Peer leaders grow from leadership and teaching opportunities in peer led team learning. Poster at the Teaching Institute at Association for Psychological Science Washington, D.C