Research Article

Replicating Peer-Led Team Learning in Cyberspace: Research, Opportunities, and Challenges

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Abstract: This quasi-experimental, mixed methods study examined the transfer of a well-established pedagogical strategy, Peer-Led Team Learning (PLTL), to an online workshop environment (cPLTL) in a general chemistry course at a research university in the Midwest. The null hypothesis guiding the study was that no substantive differences would emerge between the two workshop settings. Students in the PLTL ($n = 220$) condition were more satisfied with their workshop and earned statistically significantly higher course grades, yet earned comparable standardized final exam scores. They also had lower incidence of students' earning D or F course grades or withdrawing from the course (DFW rates) than students in the cPLTL setting ($n = 175$). Interviews with 10 peer leaders and 2 faculty members, as well as discourse analysis of workshop sessions, revealed more similarities than differences in the two conditions. The final exam scores and discourse analysis support the null hypothesis and use of both face-to-face and synchronous online peer-led workshops in early science courses. © 2014 Wiley Periodicals, Inc. J Res Sci Teach 51: 714–740, 2014

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Higher education has witnessed intentional shifts from instructor-centered to learner-centered pedagogies. Research shows that these student-centered pedagogies are more effective as students form or are placed into interdependent learning communities (Irvine, Code, & Richards, 2013; Tutty & Klein, 2008) to discuss their perceptions, exchange ideas, propose hypotheses, share procedural knowledge, and question one another's reasoning (Heller, 1992; Jewell, 2013; Tutty & Klein, 2008). Research on the impact of such pedagogical strategies has shown positive effects on student grades and persistence (Kuh, Cruce, Shoup, Kinzie, & Gonyea, 2008) as well as lead to deeper levels of understanding, critical thinking, and reasoning (Nelson-Laird, Garver, Niskodé-Dossett, & Banks, 2008; Tagg, 2003). These pedagogical strategies are also predictors of deep learning because those who learn in this manner tend to

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integrate and synthesize information with prior learning, better process information, and earn higher grades (Kuh, Cruce, Shoup, Kinzie, & Gonyea, 2007; Ramsden, 2003). Moreover, these high-impact educational practices, such as Supplemental Instruction and Peer-Led Team Learning (PLTL), often incorporate peer mentors to instruct, support, and cultivate the intellectual development of students (Goldstein, 1999; Graham, Frederick, Byars-Winston, Hunter, & Handelsman, 2013; National Academy of Sciences [NAS], 1997) since problem solving in collaboration with peers is more effective than independent problem solving (Hampel, 2006).

Along with the growth of engaging pedagogical approaches in the higher education another area has emerged. The increased use of instructional technology within face-to-face courses has occurred alongside the explosion of courses conducted either completely online or as a hybrid course. According to a 2013 study of higher education, 6.7 million students in the United States took at least one online course (Allen & Seaman, 2013). A critical question arises regarding compatibility of the two parallel phenomena in college science courses. Can you meet the demand for engaging pedagogies in online instructional spaces? If you use the same pedagogy in the two environments, what are the differences in learning outcomes, student behaviors, and instructional practices in the two environments?

There is a growing amount of research suggesting that student outcomes are the same or better in online education than traditional face to face (U.S. Department of Education, Office of Planning, Evaluation, & Policy Development, 2009; Williams, Duray, & Reddy, 2006; Wilson & Allen, 2011). Multiple research studies have demonstrated that there are comparable student satisfaction scores and no significant difference in student achievement between blended and traditional courses (Aragon, Johnson, & Shaik, 2002; Block, Udermann, Felix, Reineke, & Murray, 2008; Du, 2011; Lightner & Lightner-Laws, 2013; Utts, Sommer, Acredolo, Maher, & Matthews, 2003; Ward, 2004), likely because today's students are "dependent on communication technologies for accessing information and for interacting with others" (Michael, 2012, p. 156; Oblinger & Oblinger, 2005). In "Getting the Mix Right Again: An Updated and Theoretical Rationale for Interaction," Anderson (2003, p. 2) proposed that "no single medium is superior to the others for supporting the educational experience. Deep and meaningful learning will occur if at least two of three forms of interaction are present: student–teacher; student–student; student–content."

Most studies that compare student learning outcomes in online (greater than 80% of course content delivered online) versus face-to-face (less than 30% of course content delivered online) courses focus on course grades and final exam scores (Jaggars, 2011), yet this mixed methods study incorporates an analysis of students' deep learning in face-to-face and hybrid versions of a course. Our purposeful emphasis on assessing student engagement and retention, in the form of DFW rates, was selected since these two factors have been linked to academic success for all ethnic groups (Kuh et al., 2010; Tinto, 1993). Since members of socially stigmatized groups, such as under-represented minorities and low-income students, can be uncertain of their social belonging in school (Walton & Cohen, 2011), the positive peer interactions fostered in PLTL environments (Mauser et al., 2011) could combat the social isolation that would lead to diminished intellectual achievement (Walton & Cohen, 2011). Thus, student achievement will be examined with regard to the student demographics in the face-to-face PLTL and cPLTL settings.

Few studies have explicitly compared online versus face-to-face learning in entry-level chemistry courses and none have examined the impact of moving a well-established active-learning pedagogical intervention, such as PLTL in a science course, from a face-to-face environment to a synchronous online environment (Phipps, 2013). Furthermore, there is a paucity of studies examining team learning in face-to-face versus virtual settings (Tashiro, Hung, & Martin, 2011). This research study tested the null hypothesis that there would be no differences when face-to-face PLTL was transitioned to an online, synchronous setting, dubbed cyber PLTL (cPLTL). In order to test this hypothesis, three underlying questions guided the study: (i) what, if any, student learning outcomes differ for students in PLTL and cPLTL workshops; (ii) what, if any, quality and depth of educational discourse differ between PLTL and cPLTL workshops; and (iii) what, if any, pedagogical strategies differ between peer leaders in PLTL and cPLTL?

Theoretical Framework

This study is grounded in a social constructivist theoretical framework (Bodner, 1966, 2004; Bodner & Klobuchar, 2001; Driver, Newton, & Osborne, 2000; Scardamalia & Bereiter, 2006; Walker & Sampson, 2013; Watson, 2001), which asserts that "knowledge is constructed in the mind of the learner" (Bodner, 2004, p. 621) through social interactions. According to Gergen (1995), knowledge is generated and authenticated by the social interchanges between students, in which they endeavor to develop common language and understanding. Vygotsky (1978) proposed that the difference between the learning a student could achieve in isolation and the potential achievement that could be attained with assistance from capable peers is the Zone of Proximal Development (ZPD). Faculty encourage this development of students in their ZPDs by both providing challenging materials and training peer leaders to scaffold student learning, rather than merely provide answers. One educational intervention that strategically partners trained peer leaders with students of varying abilities to collaboratively solve challenging problems in order for students to develop within their ZPDs is PLTL (Gafney & Varma-Nelson, 2008).

Peer-Led Team Learning

PLTL is a "socio-collaborative learning task" in which students are motivated to actively participate because the problems are complex enough to invite the sharing of conceptual knowledge, differing problem-solving procedures, justification of ideas, and consensus building (Hampel, 2006). Just as scientists do in the real world, students in PLTL workshops learn to construct meaning and understanding of new concepts introduced in lecture by working in groups, debating, negotiating, and building consensus (Gilliver, Randall, & Pok, 1998). Thus, PLTL provides a unique opportunity for students to construct new conceptual understanding that is often missing in standard curricula (Cracolice & Trautman, 2001). Therefore, PLTL is intended for all students in a course; it is an integral part of the course and not intended just for at-risk students. Furthermore, PLTL can be implemented in all types of STEM courses, class sizes, and institution types (Gafney & Varma-Nelson, 2008).

The PLTL model of teaching preserves the lecture and replaces the recitation with a required weekly 2-hour session, during which approximately eight students work as a team to solve carefully structured problems under the guidance of a trained peer leader (Eberlein et al., 2008; Gosser et al., 2001; Gosser, Kampmeier, & Varma-Nelson, 2010; Varma-Nelson & Coppola, 2004; www.pltl.org; www.pltlis.org). The developers of the PLTL model identified six "critical components" vital to ensuring the success of a PLTL program (Gafney & Varma-Nelson, 2008, pp. 103–104), including:

- *Faculty involvement*. The faculty members teaching the course are closely involved with the workshops and the workshop leaders.
- *Integral to the course*. The workshops are an essential feature of the course.
- *Leader Selection and Training*. The workshop leaders are carefully selected, well-trained, and closely supervised, with attention to knowledge of the discipline and teaching/learning techniques for small groups.
- *Appropriate materials*. The workshop materials are challenging, intended to encourage active learning, and are appropriate for groups.

- *Appropriate organizational arrangements*. The particulars, including the size of the group, space, time, noise level, etc., are structured to promote group activity and learning.
- *Administrative support*. Workshops are supported by the department and the institution as indicated by funding, recognition, and rewards.

Lastly, the peer leaders are students who have done well in the course previously and are trained weekly with collaborative learning techniques to facilitate the workshops. The peer leader is central to the model and is trained to ensure that the team members engage in discussions and debate as they strive to find solutions to the workshop problems without the peer leader actually giving them the answer. He or she guides this process by asking questions and facilitating group interactions. A good leader encourages students to take responsibility for their own learning and focuses their efforts on negotiating meaning and constructing individual understanding.

The impact of PLTL on students, leaders, faculty, and institutions has been continuously assessed and evaluated in a variety of settings (Báez-Galib, Colón-Cruz, Resto, & Rubin, 2005; Hockings, DeAngelis, & Frey, 2008; Lewis & Lewis, 2005; Lyon & Lagowski, 2008; Peteroy-Kelly, 2007; Prezler, 2009; Tien, Roth, & Kampmeier, 2002). Faculties have used exam points, course grades, and scores on standardized national exams to evaluate student performance and retention. In one study, 18 early adopters compared percent success (percentage of ABC grades) by PLTL students versus non-PLTL students. The aggregate data are compelling: on average across institutions, disciplines, courses, and faculty, 4,800 PLTL students earned 14% points higher ABC grades (76%) than their non-PLTL counterparts (62%; Gafney & Varma-Nelson, 2008). In addition to a measurable impact on student performance, PLTL provides peer leaders with unique opportunities to revisit course content from a different perspective and to establish new relationships with faculty, staff, and fellow students. Thus, serving as a peer leader can be transformative for the students (Gafney & Varma-Nelson, 2007). Furthermore, 723 students in a 1996 study of 9 schools and 16 courses responded to a Likert-type scale survey regarding their experiences in PLTL workshops (Gafney, 2001). Eighty-two percent of the students agreed that they would recommend workshop courses to others; fewer than 10% disagreed. Furthermore, 87% of the students agreed that, "In Workshop, I am comfortable asking questions about material I do not understand;" only 6% disagreed (Gosser et al., 2001, p. 79). PLTL has been implemented for almost two decades at the university that performed this research.

Cyber PLTL (cPLTL)

Grounded in PLTL methodology, cPLTL situates the small groups' problem-solving discussions in a synchronous online setting rather than face-to-face environment, transforming the university's first-semester general chemistry course to an optional hybrid course, in which cPLTL students attend the same face-to-face lecture as their classmates, but elect to participate in synchronous online workshops rather than face-to-face workshops (Mauser et al., 2011; McDaniel et al., 2013; Varma-Nelson & Banks, 2013; cPLTL.iupui.edu). In cPLTL, six to eight students and a trained peer leader participate in the virtual workshop session by logging into a web-conference, such as an Adobe Connect meeting. After logging in, each participant shares his or her webcam, microphone, and USB document camera. With guidance from the peer leader, the students complete problem sets, case studies, or other course-related content. The document camera share window permits students to observe one another's work, make comments, and provide peer guidance. Students may also form small groups and meet in virtual rooms to collaborate before reuniting with their full groups to discuss problems. Throughout the session, the peer leader maintains the ability to observe and interact with all participants. The cPLTL setup is similar to that of a two-way audiovisual data and document cameras, PictureTele, that enabled students at different locations to view student work with a document camera, but the statistics course Brown and Kulikowich (2004) studied did not include peer-facilitated collaborative group work. Similarly, the *Interwise* synchronous e-learning system utilized by the Open University of Hong Kong provided audio of classmates and visuals of shared files, but provided neither webcam view of classmates as they worked in partnership nor collaborative problem-solving activities (Ng, 2007).

The cPLTL synchronous online workshop environment utilizes a combination of common web conferencing service user interface components (Mauser et al., 2011; McDaniel et al., 2013), including:

- *Participant's list*—displays the names of all participants who enter the room. This list permits the peer leader to identify who enters or exits the room during the session.
- *Audio/video sharing window*—enables all participants in the workshop to see and hear each other during the virtual session.
- *Chat window*—enables peer leaders to share instructions or web links to educational resources for activities. It can also be used as an alternate method of communication if a technical glitch were to occur with headsets, microphones, or web-cameras.
- *Presentation window*—enables each student to share his or her own work with the *document camera* while viewing the work of all other participants at the same time. This setup allows for an environment in which students can collaboratively engage in problem-solving.
- *Two cameras*—the principal technology component of cPLTL is the capacity to use two cameras simultaneously. The document camera displays each participant's work while web-camera captures the real-time image of the student.
- *Recordings*—the peer leaders are trained to automatically record all cPLTL sessions, providing a valuable resource for faculty, peer leaders, students, and researchers.
- *Constant access to workshop recordings*—students have access to the recordings of their workshop sessions, so they can review conversations any time.

Throughout the process of transitioning PLTL to an online setting, a major goal was to maintain the underlying value of PLTL. Beyond the obvious differences between physically being with others or congregating in a virtual room, the attempt was to keep the practices similar (Table 1). Peer leaders were trained to use effective questioning skills, redirect off-task chatter,

Table 1
Comparison of PLTL and cPLTL components

Component	PLTL	cPLTL
The professors are involved in the selection of materials, weekly training, and supervision of the peer leaders for the Workshops.	✓	✓
The weekly 2-hour Workshops are an integral part of the course.	✓	✓
The peer leaders are selected, trained, and supervised to be skilled facilitators of group work.[a]	✓	✓
The Workshop materials are appropriately challenging, relevant, and directly related to material covered in lecture.	✓	✓
The Workshops are supported by the department and institution with funds, course status, and other support.	✓	✓
No answer keys are provided for the Workshop problem sets.	✓	✓
The Workshops' groups consist of small group of students.[b]	8–10	6–8
Students are trained in the technology utilized in the Workshops (*Workshop Zero*).[c]	✓	

Note: [a]Additionally, cPLTL leaders are trained to use Adobe Connect and IPEVO document camera to facilitate their workshops.
[b]Limitation on internet speed and bandwidth allows a maximum of eight students per cPLTL section.
[c]Technology training for cPLTL students is done in *Workshop Zero* so that cPLTL students can spend equal amount of time on chemistry content as PLTL students in Workshops.

attend to both verbal and non-verbal cues, encourage engagement from the more shy students, and monitor the overly-engaged from dominating the discussion. Minor differences in peer leader training occurred at the beginning of each semester as time was spent on learning to troubleshoot technological challenges.

Purpose

The purpose of this study was to determine if the transition of PLTL workshops in a general chemistry course to a synchronous online setting would produce comparable student outcomes. The expectation from the beginning was that there would be minor technical challenges, but once addressed, the underlying value of PLTL would transfer to the online condition. Multiple measures of student learning were documented and analyzed to test the null hypothesis, including: student dialog and perceptions from peer leaders and faculty.

Methods

Setting

The site for this study is an urban research university in the Midwest with a diverse student population. This primarily commuter campus has approximately 30,000 students. The demographics of the undergraduate population include 15% underrepresented minorities; 36% are 25 years or older; and 68% work for pay off campus, who on average work for 28 hours per week. The PLTL program at this university has achieved sustained success as evidenced by previous internal assessment studies. The DFW rates for fall semesters decreased from above 45% before PLTL was implemented to below 20% in 2008. The withdrawal rate also decreased from above 25% to less than 10% (Varma-Nelson & Banks, 2013). A survey of 412 students in fall 2007 showed that 56.3% of them believed PLTL was significantly helpful to their study of chemistry and 26.9% believed it was helpful. The majority of peer leaders reported that serving as PLTL leaders increased their problem-solving skills (96%), self-confidence (87%), communication skills (96%), and ability to work with others (100%). Over half (58%) of the leaders believed the PLTL program increased their interest in teaching, and 29% reported that it influenced their choice of future career direction. In 2009, the university began offering cPLTL workshop section options to the available list of PLTL sections. Additional specific trainings for students and peer leaders in cPLTL sections were held to provide them technological training as well as afford peer leaders with strategies for enhancing online engagement.

Participants

A total of 395 students participated in the study over the course of six academic semesters. During the registration timeframe, students were provided an option to enroll in either PLTL or cPLTL workshop sections. One hundred seventy-five students self-selected into cPLTL workshops. A total of 220 students were identified as part of the PLTL control condition. Each semester an equal number of comparison PLTL sections were selected. Selection criteria included both peer leaders with comparable experience and peer leaders who taught cPLTL and PLTL in a single semester. Students' gender, ethnicity, and Pell Grant eligibility status were obtained from the university after obtaining permission from the institutional review board (IRB). The demographic makeup of the two groups was similar in terms of gender, socio-economic status, and racial makeup. Students in the cPLTL sections were older with approximately 40% older than 23 years of age as compared to less than 15% in the PLTL sections. PLTL workshop sections contained between 8 and 12 students and the cPLTL sessions were somewhat smaller having between 6 and 8 students per workshop, due to technology constraints. A total of 11 peer leaders and both chemistry faculty members who taught the course participated in one-on-one interviews.

Materials

The same workbook, developed by faculty members of this university's Department of Chemistry and Chemical Biology, was used in both PLTL and cPLTL workshops (Malik & Zhu, 2013). It consists of 15 units and covers all topics typically taught in a first semester general chemistry course. There are three parts in each unit: (i) A Self-Test, to be completed by students before attending workshop; (ii) Workshop Problems, to be completed collaboratively by students during each weekly workshop; and (iii) Post-Workshop Exercises, to be completed by students individually after the workshop to test their understanding. The level of most problems in the workbook is slightly above what an average student can solve individually in order to encourage students to work collaboratively during the PLTL and cPLTL workshops.

Data Collection

Student Achievement. End of course grades were used to assess students' course performance. Student letter grades earned in the course were calculated into a 4-point GPA scale (A = 4.0, A− = 3.7, B+ = 3.3, B = 3.0, B− = 2.7, C+ = 2.3, C = 2.0, C− = 1.7, D+ = 1.3, D = 1.0, D− = 0.7, F = 0) for analysis. The American Chemical Society (ACS) 2005 First Semester General Chemistry exam is a 40-item, paired question, end-of-course assessment measuring acquired content knowledge that is used as the final exam in addition to comprising 24% of the course grade.

Student Perceptions of Workshops Survey. Students enrolled in both PLTL and cPLTL completed a *Student Perceptions of the Workshop* survey. The survey contained 10 Likert-type scale (1—strongly disagree to 4—strongly agree) questions and asked questions about participation in the workshop. Sample items included, "My interactions with my peer mentor were helpful in increasing my understanding of the material taught in this course" and "Choose the options that best describe which course you enrolled in and why."

Student Discourse in Workshops. All cPLTL sessions, recorded through the Adobe Connect software, included the various online classroom components: spoken dialog, chat pods, the white board, and camera views of each student and the peer leader. Similarly, audiovisual recordings were obtained from PLTL workshops with comparable student demographic makeup via use of flip cameras during sessions at the beginning, middle, and end of the semesters to enable the researchers to examine PLTL and cPLTL sessions that covered identical course content.

Interviews. Formal interviews were conducted with selected peer leaders and university faculty involved in creating the course and workshop materials. Interviews lasted 30–45 minutes. Each interview followed a semi-structured protocol and enabled researchers to obtain a more contextualized understanding of experiences in cPLTL. Sample interview questions included, "How does the online forum affect student learning and/or engagement in your workshop?" and "Describe how training and mentor support for cPLTL and PLTL differ." Interviews were audiotaped and transcribed verbatim.

Data Analysis

Descriptive statistics were generated for student course grades, retention rates, and Likert-type-scale-based student survey data. Once the normality of the data was verified with regard to skewness and kurtosis, independent *t*-tests were conducted to compare surveys responses, mean course grade, ACS 2005 First Semester General Chemistry exam scores, and frequencies of discourse categories in the PLTL and cPLTL courses. Chi-squared tests were performed to examine any differences in percentage of DWF grades and ABC grades by type of workshop. *Post hoc* analysis consisted of a chi-squared test to examine differences in DWF and ABC grades by demographic indicators of race and socioeconomic status.

A total of 24 PLTL workshops were included in the qualitative analysis, including beginning of semester, middle of semester, and end of semester workshop sessions for four peer leaders in both face-to-face and cyber sections. Critical incidents of student dialog were identified and transcribed as instances in which students expressed discourse indicative of deep learning. The critical incidents identified for this portion of the study were coded with an analytic framework based on the work of Elder and Paul (2013) and Michaels, O'Connor, and Resnick (2007), with the addition of a critical thinking category (Table 2). This framework is held in contrast to O'Neal's (2009) learning effectiveness framework, which measured student satisfaction, participation, and performance, and Rivera and Rowland's (2008, p. 15) definition that powerful learning consists of experiences that stand out in memory, impact the students' thoughts and actions over time, or influence student knowledge application under diverse circumstances. Our analytic framework was more appropriate for the purposes of this study than those of O'Neal (2009) or Rivera and Rowland (2008) because the researchers wanted to assess students' intellectual engagement with the course content that could lead to long-term content memory rather than students' feelings of satisfaction, students' perception of their participation or performance, or formative emotional experiences. Two of the co-authors coded the transcripts of student dialog independently, using the deep learning category definitions shown in Table 2, resulting in an inter-rater reliability of 89% and, after discussion, the inter-rater reliability rose to 95%.

In addition to analyzing the PLTL and cPLTL transcripts according to the analytic framework described above, thematic analysis of the qualitative data was conducted by third co-author, utilizing the constant comparative method (Glaser & Strauss, 1967; Guba & Lincoln, 1994; Lincoln & Guba, 1985). One of the researchers applied open coding representing the sentiment of each paragraph or data cluster of qualitative artifacts and developed codes identifying patterns within the data themes (Creswell, 2008; Hill et al., 2005). Finally, representative examples for each emergent theme were identified from observations, interviews, and workshop session transcripts. Then, the entire team collaborated to share findings and confirm agreement of coding selections, which resulted in specific themes.

Table 2
Deep learning categories for student discourse

Category	Definition
Accuracy	Communicating an answer to affirm its correctness
Analysis	Examining, deconstructing, distinguishing, interpreting, categorizing, summarizing, or exploring theories or concepts by determining cause and effects and exploring parts and patterns
Application	Using or employing theories or concepts in problem solving
Clarity	Providing a clear, well-defined, and appropriate example to convey what he/she means
Critical thinking	The mental process of actively conceptualizing, applying, analyzing, synthesizing, and evaluating information to reach an answer or conclusion.
Meaning construction	Extending peer contributions by connecting peer comments to new concepts, building on peers' current understanding to advance to more complex levels; finding relationships between existing knowledge and new information.
Reflection	Recalling and consciously deliberating on information, concepts, and theories from previous workshop session, class notes, texts, manual, or lecture slides.

Results

Academic Achievement

Although *t*-tests of mean course grades and ACS General Chemistry exam scores indicated that there was no significant difference between the two settings (Tables 3 and 4), chi-squared analysis indicated that there was a significant difference in ACS versus DFW grades for PLTL and cPLTL students. Furthermore, the histogram of student course grades by setting revealed that the largest differences in the number of students earning particular grades relate to A, B, and W course grades (Figure 1). *Post hoc* analysis revealed that there is a statistically significant difference in successful completion of the course for underrepresented minority cPLTL students ($p < 0.05$, effect size $= 0.75$; Table 5). Likewise, there is a statistically significant difference in successful completion of the course for low-income cPLTL students ($p < 0.05$, effect size $= 0.49$; Table 6).

Workshop Experiences

Chi-squared analysis indicated that there was a statistically significant difference in student perception survey responses regarding the preference for online workshops ($\chi^2 = 71.70$, df $= 2$, $p < 0.05$). Students enrolled in the face-to-face PLTL generally had higher item mean scores than their cPLTL counterparts, particularly in the areas of understanding and comfort level asking for assistance when necessary. PLTL students ($M = 4.43$) were significantly more likely than cPLTL students ($M = 4.20$) to report that interactions with their peer mentor were helpful in increasing their understanding of the material taught in the course with 81.3% of cPLTL and 88.7% of PLTL students indicating they agreed or strongly agreed. cPLTL students on average were relatively neutral on their preference for online workshop, while PLTL students preferred face-to-face. Although the student perception survey results largely do not challenge the null hypothesis of comparable student workshop experiences, analysis of interviews and discourse suggest a difference of student experiences in the two settings.

Table 3
Final course grades (Fall 2010–Spring 2013)

	cPLTL		PLTL	
	N	*Mean (SD)*	*N*	*Mean (SD)*
Mean course grades	175	2.26 (1.16)	220	2.43 (1.15)
	N	*% Earned ABC*	*N*	*% Earned ABC*
ABC grades	137	69.2%	180	78.3%*
	N	*% Earned DFW*	*N*	*% Earned DFW*
DFW grades	61	30.8%	50	21.7%*

Note: Total sample size for mean course grades includes only students who completed the course.
*$p \leq 0.05$; effect size $= 0.21$.

Table 4
ACS exam scores (Fall 2010–Spring 2013)

	cPLTL		PLTL	
	n	Mean (SD)	*n*	Mean (SD)
American Chemical Society exam score	166	62.2% (17.46)	208	63.8% (16.11)

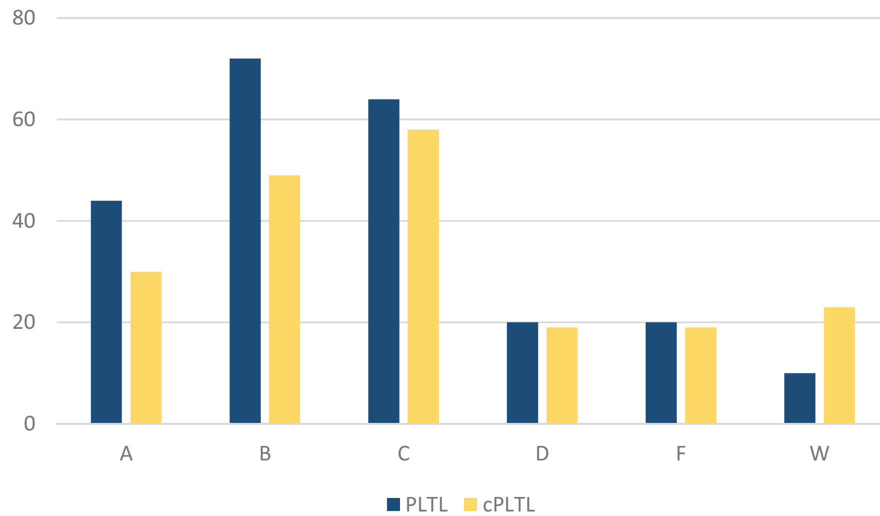

Figure 1. Histogram of student course grades by setting.

Social Connections. The qualitative data provided additional insight on students' classroom and online experiences, particularly in terms of their development as a community of learners. Most peer leaders described similar social interactions and cohesion among PLTL and cPLTL groups and attributed differences to individual personalities that varied from semester to semester. cPLTL leaders expressed:

> I constantly hear them talking about things other than chemistry while they are doing a problem, and I think this is a good thing. PLTL has never been something where we don't want students to have fun.
> The most amazing part of this online class is that I feel like I know my online students just as well, if not better, than my face-to-face workshops.
> [. . .] my fall [online] group, they were almost so talkative that you had to ask them to be quiet. My group now is almost so quiet that you have to ask them to talk. So it is just student personality differences.

Table 5
Data comparing racial differences of cPLTL and PLTL students[a]

	cPLTL		PLTL	
	Underrepresented minority	Racial majority	Underrepresented minority	Racial majority
ABC grades	9/22 (40.9%)*	60/86 (69.8%)	18/25 (72.0%)	66/79 (83.5%)
DFW	13/22 (59.1%)	26/86 (30.2%)	7/25 (28.0%)	13/79 (16.5%)

Note: [a]Discrepancies in *n* reflect demographic data available for participants.
*$p < 0.05$; effect size = 0.75.

Table 6
Data comparing income level differences of cPLTL and PLTL students[a]

	cPLTL		PLTL	
	Low income	Not low income	Low income	Not low income
ABC grades	24/43 (55.8%)*	45/65 (69.2%)	32/43 (74.4%)	52/61 (85.2%)
DFW grades	19/43 (44.2%)	20/65 (30.8%)	11/43 (25.6%)	9/61 (14.8%)

Note: [a]Discrepancies in *n* reflect demographic data available for participants.
$^{*}p < 0.05$; effect size = 0.49.

Likewise, peer leaders responded to nonverbal student cues to ensure student understanding in both face-to-face and cyber settings. However, while students appeared comfortable working together in the audiovisual recordings of cPLTL sessions, some leaders suggested the relationships formed in cPLTL may not translate into social connections outside of the workshop, as has been observed with PLTL participants. For example, some students did not engage with leaders or even recognize their group members when they encountered them on campus. Peer leaders also noted that the virtual nature of cPLTL limited their ability to incorporate activities that work well with traditional PLTL groups in enhancing social interactions within the workshops. For instance, some leaders would coordinate creative learning activities for PLTL workshops in which students could create and enjoy edible chemistry models. Peer leaders would also bring pizza, baked goods, and other treats to celebrate a holiday or reward the groups for having done well. These kinds of informal social interactions aid in building a sense of community among students, and most of the activities were not logistically possible online in cPLTL.

Both peer leaders and students felt that attending a cPLTL workshop allowed them the freedom to work from home and assisted in their work-life balance. One peer leader shared, "I think it gives more options for people who otherwise wouldn't be able to do this [. . .] I think convenience is a huge factor in the success of cPLTL specifically." In addition to the convenience of cPLTL, peer leaders and faculty members felt that the online format of cPLTL provided students with a safe space where they could ask questions. One faculty member shared, "Because they are more comfortable [in the cPLTL format] and they are at home, and they have a certain comfort level, I think they are less scared of making a mistake." Most peer leaders and faculty noted during their interviews that a large number of successful interactions occur during the cPLTL sessions.

Deep Student Learning. The analysis revealed that student discourse exchanges representing all six categories of deep learning were heard in both the PLTL and cPLTL environments (Table 7). The total number of critical incident occurrences of each deep learning category from each setting is shown in Table 8, along with the percent of total that this represents. Below the total and percentage values, the mean and standard deviations derived from the combined sessions of the four peer leaders is given for each setting (i.e., for each leader, the frequency of critical incidents of that deep learning category were summed for each peer leader across the three sampled sessions). Then, seven paired *t*-tests (two tails) were calculated to determine whether the manifestation of these deep-learning categories was comparable or different in the two settings. As shown in Table 8, the cPLTL students expressed significantly higher clarity statements in the sample of observed discourse, while PLTL students expressed significantly higher accuracy and analysis statements in the sample of observed discourse. Discourse analysis revealed that PLTL students first asked one another their answer for a problem to decide whether or not to discuss it (accuracy discourse), then proceeded with a critique of one another's work (analysis discourse) only if their

Table 7
Student discourse examples which reflect deep learning

Category	PLTL	cPLTL
Accuracy	S1: So, do you guys want to check them one by one to see if we have the same answer? S2: Yeah.	S1: For b, I had for the balanced equation, 4, 3, and 2. And then I had 4.00 moles of iron. S2: I had that, too. S3: Yeah, me, too.
Analysis	S1: I don't see how you got that 'cause you only have six oxygens. S3: Right. You have 1,428.5 times 6. S2: See, there's 6 O_2's. S3: Oh, you multiply that by 6 to begin with. S2: Yeah. You figure out how many carbon-carbon bonds, how many carbon-hydrogen bonds, and oxygen-oxygen bonds are each broken and add them up.	S1: Um, I do have a question really quick from where we left off. S2: What's up? S1: So, the molar mass, you said, goes along with the molecular [. . .] formula, so now that I have got the formula from the empirical formula, what do I do to move on to getting the molecular formula.
Application	S1: [. . .] I used Avogadro's number to convert atoms to grams. S2: (pointing to S1's workbook) You mean moles. . . . S2: Yeah. Remember that's 63.5 amu times two, so your [conversion factor] is in grams per mole of Cu_2. Then, you'd divide by Avogadro's number. S1: Oh, so you divide the number of atoms by 6.02×10^{23}. S2: And then multiply by 127 grams per mole for Cu_2. S1: Right! And that's how you calculate how many atoms in 1.24 grams of copper in the salt.	S2: I just left the C_2H_5OH and then put it was 3 before the O_2 and then 2 CO_2, and then $3H_2O$. S1: Oh, I see. I didn't reduce enough. S2: Every time you do a balanced equation, you have to make sure it is reduced all the way.
	Clarity	S1: So, I divided the amount of what I had by eleven to get this number (pointing at the calculation in his notebook), then multiplied by the molar mass of it since that would be the weight of the hydrate. It's sort of the number of times.
	S2: Would it be possible to write that out? PL: Yeah, that would be a good idea. S5: Yeah, working on it here.	
Critical thinking	S1: I don't see how you got that 'cause you only have six oxygens. S3: Right. You have 1,428.5 times 6. S2: See, there's 6 O_2's. S2: Yeah. You figure out how many C-C bonds, how many C-H bonds, and O-O bonds are each broken and add them up.	S2: Hey, Dawn, if you can hear me, you're doing a lot more work than you have to right there. S3: I am. Ok. Is there a different [. . .] am I doing it wrong completely?

Category	PLTL	cPLTL
Meaning construction	PL: It's combustion. What happens in combustion? Adam?	S3: OK, so, you fill out. I understand you have 16 balanced electrons. I see now. It makes more sense as to how it's structured: the 2s the antibond and 2p and anti-bonds. So you fill up all the normal, just the regular 2s2p. You fill those up first, right?
	S1: Something to do with hydrogen.	S1: Yeah, you go from the bottom up.
	PL: You add oxygen. And form what?	S3: You fill up 2s, then you fill up 2s*, then 2p, and then 2p*.
	S2: CO_2 and H_2O.	S1: Yep.
	PL: Okay. So add oxygen to what they gave you, write the products CO_2 and H_2O, and	S3: Ok.
	S2: Oh, stoichiometry!	
	PL: How many carbon-carbon bonds are breaking?	
	S2: Six and fourteen hydrogen-oxygen bonds are forming.	
Reflection	PL: The only definition I'm concerned about here is bond order. What did you guys have for that?	S1: So, number 4, when it forms aluminum oxide. Is that a formula that needs to be memorized?
	S2: When I think about what he [...] what we're supposed to take those bonding electrons minus those that are anti-bonding electrons and divide by two.	S2: Um, you can figure it out by like, if you start with writing a balanced equation. If you look at my screen, I'll show it. Ok. Aluminum oxide, when you start the balanced equation, is aluminum plus oxygen, which would be O_2 because it is one of the diatomic molecules [...] Aluminum oxide is [made of] Al^{+3} and O^{-2}, so it would be Al_2O_3. Does that make sense?

answers were different from each other. In contrast, cPLTL students' discourse usually focused immediately on the method to solve each problem, as indicated by the significant difference in occurrence of clarity statements, rather than merely confirming answers. Additionally, the discussion of multiple methods to solve a problem was encouraged in cPLTL, while PLTL students moved on to the next problem if they had the same answer. The problem-solving focus emphasized by the cPLTL students was better aligned with the overarching goal of PLTL: students deliberate

Table 8
Frequency of deep learning discourse in each setting

	PLTL ($N = 64$)	cPLTL ($N = 73$)
Accuracy	21 (33%)[a] ($m = 5.3$ (SD 1.5))	8 (11%)[a] ($m = 2.0$ (SD 0.8))
Analysis	21 (33%)[b] ($m = 5.3$ (SD 2.2))	5 (7%)[b] ($m = 1.3$ (SD 1.3))
Application	13 (20%) ($m = 3.3$ (SD 1.0))	24 (33%) ($m = 6$ (SD 2.2))
Clarity	2 (3%)[c] ($m = 0.5$ (SD 0.6))	17 (23%)[c] ($m = 4.3$ (SD 1.5))
Critical thinking	2 (3%) ($m = 0.5$ (SD 0.6))	3 (4%) ($m = 0.8$ (SD 0.5))
Meaning construction	4 (6%) ($m = 1.0$ (SD 1.1))	9 (12%) ($m = 2.3$ (SD 2.6))
Reflection	1 (2%) ($m = 0.3$ (SD 0.5))	7 (10%) ($m = 1.8$ (SD 2.1))

Note: [a]$p < 0.05$; effect size = 0.19.
[b]$p < 0.05$; effect size = 0.30.
[c]$p < 0.05$; effect size = 0.39.

how to solve challenging problems in order to construct deeper understanding of concepts. In this sampling, there were no other observed differences that were statistically significant, although by inspection of the table, a number of other categories might become significantly different with a greater number of samples, such as meaning construction categories of discourse.

In recordings from the earlier part of a semester, peer leaders commonly intervened when collaborating students seemed to reach an intellectual impasse in order to ask leading questions until the students were inspired to continue interdependently. Notably, there were several instances in later recordings in which the peer leader revealed that he or she had been exercising personal restraint in order to foster students' analysis, collaboration, and correction of one another's work without the intervention of the peer leader, a behavior that demonstrates the gradual removal of peer leader scaffolding as students learn to scaffold one another's learning. Thus, a culture of students seeking explanations from one another to construct meaning, rather than a peer leader or instructor, is created and reinforced in both PLTL settings, although this culture was observed more frequently in the cPLTL setting than in the face-to-face PLTL setting.

Technology Challenges and Opportunities. During the first workshop sessions when cPLTL was being implemented, technology difficulties were often described by peer leaders as interfering with student engagement time and causing problems in communication and collaboration. Over time, however, the students became more familiar with the technology and cPLTL sessions became much more effective. When describing multiple technology problems, one peer leader described how students in the cPLTL adapted and worked through those:

> I will say this though; they still truck along whenever there are problems. This first time Adobe kicked me out, it took me almost 3 minutes to get back in. I almost texted/called one of my students to let them know that I hadn't abandoned them, that I would be back ASAP. Adobe suddenly started working, and I popped back into the room to hear them talking about the problem just as if I had never left. In fact, after listening for a few moments, they asked me if they were on the right track. They had no idea I was gone, because they spent the entire time talking to each other and troubleshooting the problem on their own. I thought that was wonderful.

In addition to students adapting to technology glitches, peer leaders also worked hard to adapt, troubleshoot, and make changes to ensure that their students received instruction and that material was sufficiently covered. Hardware requirements, steady broadband strength, and software optimization training are an integral part of cPLTL implementation. The start of the semester during preliminary implementation seemed to be especially challenging. One peer leader commented:

> I have to say I think the first two weeks were gruesome between the cameras. They communicated that I can hear you but I can't see you. Or I can see you but I can't hear you. Then there is an issue with sometimes the headsets, there was an issue where you hear static. Everybody would be taking off their earphones to get the static off.

Workshop Zero, a technology training in which no chemistry is discussed that is provided for cPLTL students prior to the first scheduled workshop, was introduced to help students address technological setup difficulties prior to the first PLTL session in order to equalize cPLTL and PLTL student experiences and improve their technology self-efficacy (Marchand & Gutierrez, 2012; Repman, Zinskie, & Carlson, 2005). Additionally, student use of either a headset or utilization of both the computer's microphone and individual earbuds has subsequently been the best practice to eliminate the distractions of static feedback. Furthermore, *Workshop Zero* ensures that students receive the prompt technological and pedagogical training necessary to foster effective communication, thus preventing negative student attitude toward online learning that could occur when students' communication needs are unmet (Edwards & Rule, 2013), since students can focus on learning content only after their technological needs are met (Blocher, Montes, De Willis, & Tucker, 2002). This study's findings show that issues such as those mentioned above can be effectively prevented through orientations, practice workshops, and support of experienced technology staff. Specifically, preparation for cPLTL workshops through peer leader training, student orientation, and *Workshop Zero* aided in familiarizing students and leaders with online learning environment, best practices for optimizing computer settings, and expectations for participation practices.

The technology appeared to play a significant role in the frequency and method with which students engaged with the course materials and each other. For example, cPLTL students utilized web sources to better understand the material and better explain or support their conclusions, as indicated by the higher frequency of reflective deep learning behavior, while PLTL students typically only occasionally referred to their course notes and textbook and rarely accessed online educational resources during workshops. cPLTL peer leaders were able to immediately pull up and share visual aids to help explain difficult concepts to the entire group in a similar manner to how they would a chalkboard in a classroom, as one peer leader indicated, "You just pull the screen online. I'll show them something. I'll just pull up Paint, and I'll just use that as my whiteboard." One cPLTL peer leader discussed the ease and convenience of utilizing online educational resources, "You have the entire web at your fingertips. If you need something whether it is a conversion factor [. . .] or you want a visual aid, you can pull it off and have it there in a second." These peer leaders also simultaneously shared videos with groups to demonstrate 3D molecular models, as this peer leader indicated, "You can find a YouTube video that demonstrates something and share that. You can even pull in the lecture and notes and put it right there in a pod for them to see." The virtual environment and the technology offered easy access to a number of educational resources as well as useful ways to monitor student progress and how well they understood the course material. In contrast, face-to-face peer leaders did not encourage or utilize electronic tools and educational resources, although their use was not prohibited by the course instructor or researchers.cPLTL peer leaders communicated that they were more intrusive in cPLTL workshops than with their PLTL groups, as one peer leader noted, "I was more intrusive than I had ever been in face-to-face because I was watching what they were doing at all times [. . .] online I think I've butted in more than I ever had in face-to-face." Similarly another peer leader expressed, "The whole workshop I listened in on both groups [. . .] I jumped in when either I heard them struggling a lot, when they asked for help, or if I saw their work needed some help." Some leaders reflected a difference in how they assisted students in face-to-face PLTL workshops as compared to cPLTL workshops, "In face-to-face [workshops], I just kind of let them [work]. I wasn't seeing what they were working on, but I was there if they had questions." Although cPLTL leaders seem to more closely examine, monitor, and ascertain student understanding during the workshops, such peer leader behavior is expected from peer leaders in both PLTL and cPLTL environments. Two factors may be contributing to this phenomenon: (i) PLTL group size at this institution is larger than the standard PLTL model; and (ii) the technology enables the peer leader to easily examine student work and behavior simultaneously even when students are separated in virtual rooms. For example, the leaders described how they could silently go into a virtual room of the Adobe Connect web conferencing program, listen-in, and quickly identify where students were having difficulties. One peer leader shared:

> Online you can pause your webcam and then you can go into a room, not turn anything on for them to hear or see you, and you can see what they are talking about [. . .] It is nice too because you can kind of hear what they are really struggling on without any bias for you being in the room.

Student and Peer Leader Experiences. The qualitative data provided context and a deeper understanding of the instructional practices, student learning, experiences, and use of technology in the workshops. Cooperative learning and scaffolding strategies along with continuous supportive feedback appears to be beneficial to the construction of student learning/understanding. A variety of instructional strategies were used to promote student learning and engagement; however, some of those strategies were used more frequently than others. When comparing the cyber and face-to-face sessions, peer leaders shared that students had comparable experiences in terms of learning and critical thinking. One peer leader stated, “Whether you are doing cPLTL or face-to-face PLTL, I feel that if done properly you can achieve the same goals in terms of developing those critical thinking skills.”

The analysis of data from PLTL/cPLTL sessions and peer leader journals revealed changes in student discourse and interactions over the course of the semester. When and to what degree student-to-student interactions occurred varied depending on group dynamics and the personal characteristics of students. At the beginning of the semester, when there was little group or social cohesion, some groups required more guidance and relied heavily on peer leaders to facilitate discussions. However, as the workshops continued and students became more at ease with their online peers, this was less of an issue. The level of interaction and discussion depended on who was in attendance—more or fewer students with a stronger grasp of the material or those who were naturally more talkative. Aware of this, peer leaders employed grouping strategies to maximize interaction and learning between small group members, but noted challenges in pairing students, particularly when there was low attendance and mostly students who valued working quietly and independently. Leaders typically experimented with different grouping arrangements to find an appropriate balance in small groups. One leader noted:

> I split the group of three (one male and two females) and a pair (a male and a female). I thought. . . I thought this would work well as it did last workshop because my very quiet student won’t speak up unless she’s the only other partner someone can ask questions to. I think that the dynamic in that group worked really well and my strong student and quiet student did the workshop as it’s meant to be completed - with little assistance from me and nearly working together the entire time.

Peer leaders further encouraged and sustained group discussion by intentionally involving all students in the workshop in the discussion, and particularly by inviting students who were initially less vocal to take the lead in explaining their approach to solving problems, which worked well in engaging students who were more reticent in whole group discussions. This strategy is shown in this leader–student interaction:

> PL: Melanie, what do you think about number 4? Andrew and Megan are kind of confused. Do you want to bail them out?
> PL: Shannon, what do you think about that?
> PL: Ahseem, can you explain to Grace how you got Al_2O_3?

The instructional strategies peer leaders used were important in the learning process during both face-to-face and cyber workshops. The most common strategy observed was the use of scaffolding. Peer leaders frequently asked essential questions tailored to the students' understanding in order to help them discover the answer or better comprehend the concept. As students worked together, peer leaders often inquired about their approaches to difficult problems and provided constructive feedback. This was generally done by asking probing questions to elicit deeper thinking about their process, such as: What do we need to know in order to determine [. . .]?; What do you think the next step should be?; What information are we given that we could use? Peer leaders also provided supportive feedback to students by commenting on the accuracy of their work and indicating when they were making proper decisions about how to approach, analyze, and solve problems (validating).

The continuous supportive feedback appears to have improved student confidence in their ability to solve problems on their own (Johnson & Johnson, 2009), as the analysis uncovered multiple instances where teaching and learning became a more cooperative and self-directed effort among students with minimal assistance from peer leaders. As students became more comfortable with each other, the students' interdependent collaborative problem solving became more frequent (Micari & Drane, 2011); they were observed discussing content, asking questions, giving examples and/or analogies, explaining their answers, and encouraging one another. An excerpt from a peer leader's journal described how this process took some time, but became very useful:

> They have gotten so much better the past couple of weeks. They are now talking the other students through the problems. Earlier in the semester, they would have to physically write out each thing they wanted to convey. Now, they are giving verbal instructions for how to set up a specific problem. They speak up when they have a question. Something else that really impressed me is that they are quick to admit their shortcomings. This was a huge breakthrough for me, because students don't normally feel they can talk about that unless they feel comfortable with their group.

Another peer leader described the group learning process, "My students always see me as another resource in workshop. They often go to each other first to ask questions and then come to me if they have a question that they can't figure out." Over time, more peer leaders noticed similar patterns in group learning, as expressed in the following statements:

> This was a difficult unit, but I felt like I didn't have much to do [. . .] I spent more time than normal just observing and less time redirecting, guiding, or explaining. I don't think this is bad necessarily, just different!
>
> They work collaboratively on their own, so I don't think I have to "force" it with a CoLT [Collaborative Learning Technique].
>
> It seems the students need less of me and more of themselves these days.

Peer leaders, and eventually students themselves, in both settings compared students' processes for determining answers even when they obtained identical answers. This behavior illustrates a key strength of the PLTL approach: Students without answer keys tend to focus on understanding the problem-solving process, engaging in critical thinking, questioning, and reflection to arrive at more-reasoned conclusions and deeper learning. In addition, the data indicate that, throughout their deliberative processes, students: (i) took more time to think through processes before speaking, (ii) questioned themselves and peers as they moved through problem-solving, and (iii) weighed the appropriateness of applying certain methods to reach conclusions.

While many students and peer leaders felt the online atmosphere was conducive to student engagement and learning, there were instances where a perception of a lack of engagement and participation in cPLTL workshops was shared. One peer leader stated, "I find my students to be less engaged with the workshop atmosphere online because they have distractions going on at home. Such as people walking around in the house; kids. They seem to not be totally immersed in the workshop." Another peer leader shared, "I have experienced some challenges in keeping them engaged online. Just because, maybe they don't see it as serious as being in a more professional setting, more structured setting." Over time peer leaders described how student engagement in cPLTL sessions increased and the time spent in workshop was more productive. For example, a leader stated, "I think that my online workshop is becoming much more comparable in efficiency to the face-to-face workshops and am excited to see as it progresses," and another, "My students completed a significant portion of a long unit in the allotted time, which is very comparable to where my face-to-face students got." Student-to-student dialog consisted primarily of: (i) questioning their peers as they worked through problem sets, both to improve their own understanding of information/concepts and to challenge the processes employed by their peers; (ii) evaluating and providing supportive feedback on peer solutions and processes; and (iii) elaborating or providing support and reasoning for their own deliberative processes.

During cPLTL workshops, before moving on to the next set of problems or topic, peer leaders worked as much as possible to ensure everyone had a clear understanding of the material, which often led to time management issues. Overwhelmingly, peer leaders described time as being a major factor when comparing the learning experiences of students in cPLTL and PLTL. In the cyber workshops, peer leaders felt that it took longer to cover the content because they checked each student for understanding, rather than holding groups accountable for correct answers, a phenomenon that tended to occur in face-to-face PLTL workshops. One peer leader stated, "Describing and making sure that my students understood the content seemed to take so much longer online rather than in person." Another peer leader described it this way, "It also seems that time goes so much faster in the online section [. . .]." Peer leaders noted that students in the cyber workshop were more willing to remain in the online room after the workshop officially ended to improve their understanding. One peer leader indicated," [. . .] online, you might be able to cover [problems] slightly more in depth. You might get them to explore a concept more deeply or to explore a term more deeply. These students also stay engaged longer to improve their understanding, as one leader noted, "They stayed after in workshop nearly twenty minutes to get everything straight which I thought was great;" and another mentioned, "Face-to-face gets out when it is supposed to get out. Online [. . .] we stay later [. . .] as long as they need to finish up their problem." The time spent on problems increased in both settings as the material became more challenging.

Discussion

This was the first study that evaluated the transition of an established active-learning pedagogy from a face-to-face setting to synchronous online setting in a chemistry course. Other studies that have looked at quality of online courses described less sophisticated technological arrangements than those utilized for cPLTL, in which students see one another's faces and workbooks, hear each other's voices, and share views of computer applications in their Adobe Connect virtual rooms. For example, Michael (2012) referred to using online reflective journals, Fishman et al. (2013) referred to "online learning" as the delivery of video recordings or PowerPoint presentations, Burnett (2003) studied computer-mediated communication that utilized a subset of components afforded by the Adobe Connect environment. Furthermore, neither the Anderson et al. (2006) report about best practices in synchronous conference moderation, Petty's (2013) evaluation of online student engagement in a math course, Peterson and Bond's (Peterson & Bond, 2004) study of online teacher preparation, Wang's (2007) study of Horizon Wimba, Marjanovic's (1999) Group Support System evaluation, nor Kontos's (2008) Live Classroom study included the evaluation of as media-rich a synchronous setting such as that of cPLTL. The unique contribution of the cPLTL approach is the facilitation of collaborative student work and the development of student-learning communities through the use of an advantageous, media-rich combination of technology (National Research Council, 1996; Seery, 2012).

The findings of this study indicate comparable educational outcomes with respect to mean course grade and ACS General Chemistry exam scores between PLTL and cPLTL students. Peer leaders utilized similar grouping strategies for collaborative learning techniques, regardless of the setting, since face-to-face PLTL workshops occur in rooms with flexible seating and the web conferencing program selected for cPLTL affords the ability to open auxiliary virtual rooms during a single web conferencing session. Likewise, observations of workshop sessions and peer leader interviews both indicated that students tended to become less dependent on the peer leader and more dependent upon one another to solve problems as the semester progressed. Interestingly, however, there is a statistically significant difference in the probability of earning ABC versus DFW grades for underrepresented minority or low-income cPLTL students. Further analysis is needed to better understand issues associated with the digital divide, attendance, and active engagement differences for these two groups.

Although the mean educational outcomes were comparable in this study, there were key differences in student interactions, experiences, and pedagogical practices. An important element of the PLTL model, whether implemented in a face to face or a virtual room, is the lack of answer keys, which creates a learning environment in which students seek input from one another. Interestingly, the types of input students seek from one another differs in the two settings. While PLTL students tended to check answers with one another and express employing theories to solve problems, cPLTL students exhibited higher frequencies of discourse related to providing clear examples to illustrate a point. This behavior may be fostered by both (i) the greater emphasis on turn-taking to speak in order to prevent noise in one's earbuds and (ii) cPLTL students' desire to confirm understanding of problem-solving process when they can not simply glance at a neighboring student's workbook in the virtual environment to see workbook writing at full size. In the Adobe Connect environment, the cPLTL students see smaller images of all classmate's workbooks all at once unless a single workbook view is afforded a full screen image, unlike PLTL who frequently just lean over and see a full-sized view of one another's workbooks. The setting-related difference in student use of or reflection on educational resources outside the workshop as well as dissimilarity in collaborative construction of meaning invite further study.

There were noteworthy differences in the social dynamics of the two settings. For example, PLTL students enjoyed treats and hands-on learning activities that foster social cohesiveness, unlike the cPLTL students. Secondly, peer leaders tended to address whole groups of PLTL students to check for understanding, while they communicated with individual cPLTL students for confirmation of understanding of concepts. The cPLTL student emphasis on clarity manifested itself with both significantly higher frequency of clarity discourse as well as extended times of cPLTL workshops to ensure that all students understood each problem before moving on to the next problem. Furthermore, cPLTL students tended to build upon one another's ideas while solving problems to a higher extent than PLTL students. The most compelling difference in student discourse between the two settings is the discrepancy in students' process to discuss problems. PLTL students commenced nearly every discussion of a problem by asking if their classmates got the same answer, then instigated an interchange about what they did to solve the problem only if their answers had been different. In contrast, cPLTL students' discourse was more focused on articulating the process to solve problems, taking care to (i) include clear examples to ensure every group member understood and frequently (ii) build upon one another's ideas to construct understanding. This propensity of cPLTL students to discuss alternative methods to solve problems is consistent with Swan's assertion that participants in online discussions may be more supportive of divergent thinking and sharing of multiple perspectives than their face-to-face counterparts (2004). Thus, the qualitative analysis uncovered important dimensions of the social dynamics, which occur in face-to-face versus online settings that mere quantitative analysis of course grades, final exam scores, and survey responses were unable to identify. The discourse analysis provided evidence that the behavior of cPLTL students was better aligned with the principles of social constructivism and PLTL than the behavior of face-to-face PLTL students in this study.

Lastly, this study uncovered differences in pedagogical activities in the two settings. cPLTL students tended to consciously deliberate on information from outside the current workshop more frequently than PLTL students. Furthermore, students and peer leaders tended to access and/or shares resources from the internet more frequently in cPLTL workshops than in PLTL workshops, although each classroom in which PLTL workshops occurred was equipped with internet-enabled computers and the same peer leaders led in both settings.

The findings of this study add to the mixed outcomes from other studies that compared student achievement in online and face-to-face conditions. Some studies showed that students in the face-to-face out-perform the online environment on exams, but not course projects (Tutty & Klein, 2008), others showed no differences in achievement (Fisher, Schumaker, Culberston, & Deshler, 2010; Lightner & Lightner-Laws, 2013; Tomlinson et al., 2013), while still others showed higher levels of course and instructor satisfaction (Johnson, Aragon, & Shaik, 2000). This study also dispels the idea that clarification and explanation aspects of learning or the development of conceptual and methodical knowledge are hindered in online settings (Al-Qahtani & Higgins, 2013; Paechter & Maier, 2010); rather, synchronous computer-mediated student interactions that engage the features of cPLTL enable comparable student collaboration to those of face to face. cPLTL students' consistent use of online resources to aid their understanding of chemistry content suggests a need for PLTL peer leaders to model and encourage technology use. These data from this study indicate that with proper training of facilitators (more knowledgeable others), appropriately challenging materials, and web conferencing technology, it is possible to create an environment that supports social constructivism.

Limitations

cPLTL has been offered in general chemistry at this research university for eight semesters and biology courses at two other research intensive universities. Data from the implementation are currently being collected and analyzed, but preliminary result of implementation fidelity measures show that cPLTL (like PLTL) is transferable to other disciplines and universities. Further research is required to explore differences in the PLTL and cPLTL settings. For example, additional student interviews and focus groups are required to uncover the reasons for statistically significant differences between face-to-face and cyber PLTL on student perceptions of the workshops and knowledge/understanding of content. A limitation to the interviews and focus group questions and discussion was that they were formative rather than summative in nature. The questions were probing students' immediate experiences and not forcing them to reflect specifically on what aspects of the workshops influenced their learning.

A higher proportion of the cPLTL students were over 23 years of age than their face-to-face PLTL counterparts (40% vs. 15%), which is aligned with the observation from several studies that online students tend to be older and in need of flexibility to accommodate full-time jobs or family needs (Howell, Williams, & Lindsay, 2003; Irvine et al., 2013; Kassop, 2003; Michael, 2012; Peterson & Bond, 2004). Future studies might employ a randomized clinical trial model to account for any selection bias. Furthermore, although students who opted to participate in the cPLTL sections of the general chemistry course were provided document cameras for the duration of the semester, the authors recognize that low-income students may not have been able to participate in the cPLTL sections due to at-home computer and broadband availability. While low-income students commonly access the Internet via hand-held devices (Jaggars, 2011), current smart phones and tablets are not equipped to incorporate document camera use, which is a key component of the cPLTL environment (McDaniel et al., 2013). The researchers did not administer an exit survey to ascertain if cPLTL students who withdrew from the course would attribute their decision to lack of reliable Internet connectedness during cPLTL workshop sessions, but note that the percentage of low-income students was comparable in the PLTL and cPLTL populations for this study. Further research is needed to explore (i) reasons for the differences in technology use in the two PLTL settings, (ii) why the student discourse and social dynamics differences did not result in higher achievement for cPLTL, and (iii) to determine if the development of scientific argumentation skills (Kulatunga & Lewis, 2013) and specific content is better learned in one setting than the other.

New problem sets and materials need to be developed and studied for their effectiveness for both cPLTL and PLTL. Since the amount of information on the Internet and the students' ability to access it is so easy more open-ended questions that utilize that information should be utilized. Our audio/visual analysis relied more on the verbatim transcripts than the visual of behavioral acts of students in both conditions. Comparative studies on the use of web-based resources and monitoring specific behaviors during the workshops will help further our understanding of how to improve the workshop experience in both face-to-face and cyber environments. This will allow researchers to examine students' social presence and sense of community in both settings (Lee, 2014; Rovai & Jordan, 2004). Finally, to date, cPLTL has been offered and studied only in a course where the students attend face-to-face lectures. It would be valuable to offer cPLTL in a course that is completely taught online.

Implications for Practice

The team's experience with cPLTL implementation has implications for faculty practice, peer leader training, assessment of students learning as well as students' understanding of their own role and responsibilities for learning in a different environment. Implications for each of the stakeholders are addressed below.

Faculty

Comparable student achievement and instances of deep learning in the face-to-face and cyber PLTL settings demonstrate that it is possible to create an environment for social constructivism in a synchronous online environment. Moreover, recent collaborations with two other universities reveal that the cPLTL experience can be duplicated in other disciplines (in this case, both were biology courses) and settings (Mauser et al., 2011). The amount of time and adaptations required for faculty to transition from a course that offers PLTL to a course that offers cPLTL depends on the web conferencing platform selected and the familiarity of the faculty with the PLTL model. The amount of effort required to implement cPLTL can be reduced by working with a well-informed instructional technologist. These professionals are present on most campuses and are often integrated into the Centers for Teaching and Learning or other faculty development units within Instructional Technology departments. The challenges of implementing cPLTL without previous experience with PLTL are more substantive. In this case, faculty first needs to learn about the PLTL model from current practitioners and/or available resources (Gafney & Varma-Nelson, 2008; Gosser et al., 2001).

The ability to automatically record cPLTL sessions provides a distinct advantage in training leaders as well as assessing student learning. cPLTL recordings can be culled for vignettes that peer leader trainers (faculty and learning specialists) can use in training sessions to spark discussions of best practices. The recordings can reveal how well the peer leaders are implementing the strategies discussed in weekly training, allowing for well-informed feedback to the peer leaders during subsequent weekly training sessions. While technological issues may sometimes emerge during the training session discussions, it is recommended that the training sessions not shift in the direction of troubleshooting technology problems. Focus should remain on the content and pedagogical issues and technology issues should be dealt with separately by the instructional technologist. The other advantage of having the session recordings is that they provide the professor of the course-unfiltered feedback about his/her teaching and how students are learning concepts taught during the lecture. Finally professors interested in doing qualitative research on student learning or peer leader facilitation styles have a large database available.

Peer Leaders

cPLTL leaders, like their PLTL counterparts (Gafney & Varma-Nelson, 2007), express both personal growth and professional benefits. In addition, given the emergence in the use of video conferencing and telecommuting, cPLTL leaders' ability to facilitate group discussions online distinguishes them from their peers. Similar to the benefits for faculty, cPLTL workshop recordings can serve as a powerful reflective and professional development tool for peer leaders. Thus, technology used to conduct cPLTL workshops also assists in the effort to develop good habits of pedagogical decision making. In addition, at this institution, all PLTL peer leaders are engaged in reviewing each other's performances by visiting two sessions per semester. cPLTL students are able to do peer review of each other by reviewing the recordings in place of attending each other's sessions.

Students

There are two interesting findings about differences in students' experiences in cPLTL and PLTL workshops that need attention in designing cPLTL experiences in the future. Peer leaders report that the "virtual nature of cPLTL limited their ability to incorporate activities that work well with traditional PLTL groups in enhancing social interactions within the workshops" and some leaders suggested the relationships formed in cPLTL may not translate into social connections outside of the workshop, as has been observed with PLTL participants Having fun and building relationships are both features of face-to-face education that are worth preserving for a good educational experience. It is recommended that the weekly cPLTL workshops incorporate some time for community-building and fun experiences, not just involve problem solving.

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