Reports from Other Journals

A Statistical Evaluation: Peer-led Team Learning in an Organic Chemistry Course

by Kenneth S. Lyle and William R. Robinson

Peer-led team learning, PLTL, also known as Workshop Chemistry, is one of five systemic reform initiatives in chemistry funded by the National Science Foundation in the 1990s *(1, 2).* Since then PLTL workshops in general chemistry, organic chemistry, and biochemistry have been implemented in more than thirty post-secondary institutions and in one Montana high school *(2, 3).* The PLTL model has also been adapted for use in the instruction of biology, physics, and computer science *(3).* The workshop model emphasizes student achievement through active learning by providing a safe, supportive environment that encourages students to express their thoughts, ideas, thinking patterns, understandings, and misconceptions. The model mimics the desired characteristics associated with effective teamwork in industry.

In their report "Implementation of a Peer-led Team Learning Instructional Approach in an Undergraduate Organic Chemistry Course" Lydia Tien, Vicki Roth, and Jack Kampmeier *(4)* describe their evaluation of the effectiveness of a PLTL program in the first semester of a sophomore organic chemistry course at a small research university in the eastern United States. The researchers employed quantitative and qualitative methods to compare the achievement, retention, and attitudes of students involved in the PLTL Workshop with those in a more traditional program. Their quantitative evaluation is the focus of this column.

The Course

Prior to 1995, the first-semester organic chemistry course under study was taught in a traditional fashion. Each week students attended 2.5 hours of lecture presented by the course instructor and 1.25 hours of recitation directed by a graduate teaching assistant. The recitations had an average class size of 20–25 students. The transmission/demonstration model of learning was prevalent in the recitation sections. The teaching assistant answered students' questions, explained assigned problems, and tried to anticipate problem areas for the students. These activities usually were driven by students' questions about problems from the text and old exams. There was little student–student interaction or discussion. Teaching assistant training occurred at weekly staff meetings that focused primarily on content and administrative issues.

In 1995 optional peer-led Workshops were offered in place of the recitations; no changes were made in the lecture portion of the course. Based on the success of this experiment, in 1996 all recitation sections were replaced by peer-led Workshops. These Workshops met 1.5 to 2 hours each week with smaller group sizes and with a peer-leader serving as a facilitator for the group who was closer in age and knowledge to the students. The learning experience was modeled on a social constructivist perspective. Students were actively involved in working to improve their understandings of the course material by openly discussing their thoughts, understandings, and misconceptions.

The peer-led sections consisted of eight students and a trained peer-leader. During these sessions the peer-leader served as a guide and support as the students worked on problems and activities designed by the course instructor. The problems and activities were integrated with the other aspects of the course. They built upon the lectures and the text, they anticipated the exams, and they challenged the students to grapple with their conceptual understanding. The emphasis of the problems was on ideas, reasoning, and conceptual understanding—not answers.

The peer-leaders were students who had recently completed the course successfully and who exhibited leadership capabilities and good interpersonal skills. Students who agreed to serve as peer-leaders were trained in methods that facilitated group interactions, that encouraged working together as a team to solve problems, and that emphasized problem-solving tactics and strategies. The training began prior to the start of the semester and continued on a weekly basis throughout the term; it was conducted jointly by the course instructor and an educational specialist. Peer-leaders earned college credit for their participation in the program.

Evaluation of the PLTL Workshop

Tien, Roth, and Kampmeier *(4)* compared groups of students who were in the more traditional organic chemistry course from 1992 to 1994 with those who were involved in the PLTL Workshop from 1996 to 1999. (The group in 1995 was not included in order to avoid possible volunteer effects.) They tested the hypotheses that the PLTL workshops would improve student performance, lead to better retention rates, and result in more favorable attitudes toward this traditionally challenging course.

Data collected included total points earned on exams, course grades, gender, and race/ethnicity; a Likert survey used to capture the attitudes and opinions of the students about the course; and several semi-structured interviews with peer leaders. The interviews were designed to explore leaders' attitudes about PLTL, the role of the leader, the nature of the team problem-solving activities, and student interactions during the workshops.

Although the control and treatment sections were not taught in the same year, there were many similarities between them. The same instructor taught the organic chemistry course over the period in which this study was conducted (1992–1999). The instructional aspects of the course (average lecture size, textbook, assignments, lecture style, course goals, content, grading, and style and rigor of examinations)

were consistent for both groups throughout the period of the study. However, the study was complicated by the fact that the institution changed its admission policies; math and verbal SAT scores suggest that the 1997 and subsequent cohorts in the course were better prepared than prior groups. Beginning in 1997 the workshop participants scored significantly higher ($p < 0.01$) than the control group participants on both the math (642 vs 623) and verbal (617 vs 599) portions of the SAT. In order to compensate for the differences in the two groups, these SAT scores were used as covariates in the statistical data analysis (ANOVA).

Some will argue that this experiment was not carried out under ideal conditions because of the lack of a true control group. However, the study does add to our knowledge of the effectiveness of peer-led team learning. As Haynie *(5)* notes:

> When a single experiment is conducted…there is a chance of error that must be accepted in that one experiment. But, if the researcher then follows this experiment with another one that avoids the potential errors of the first (while possibly accepting some of the other risks avoided the first time) and both experiments attain the same results, then there can be more confidence that some truth is being brought to focus. When still a third experiment, with yet different risks, confirms those same findings, more power is given to the argument.

In other words, although there may be flaws in a study, if the study is repeated, taking into account the flaws that have arisen, and the same general results occur, the results can be considered useful. Similar studies *(2, 3)* have been conducted involving PLTL Workshops implemented at other post-secondary institutions. The findings of these studies are similar to those in this study.

Results

Workshop participants earned more points on exams than those in the control groups (Table 1). Exam averages for the individual years as well as the overall average show that Workshop participants outscored the control group participants in all cases. For the overall means, the scores are significantly different with $p < 0.01$, where p indicates the probability that the difference is due to chance. Thus there is less than a one percent probability that the mean scores differ by accident.

Although a difference between large numbers of students may be statistically significant, as is the case here, it need not be educationally significant. However, success rates, withdrawal rates, grade distributions, and effect size suggest there is an educationally significant difference between these two groups of organic chemistry students. The effect size in this study is 0.64 for uncorrected scores and 0.56 for scores corrected using SAT scores as a covariate.

Effect size is a statistical measure of the effectiveness of a treatment *(6)*. The effect size indicates how many standard deviations lie between the means of the control group and of the treatment group. This then can be translated into a percentage of the control group that lies below the mean of the treatment group. The larger the effect size the greater the difference between two groups. In this study effect size was calculated by dividing the difference between the overall mean test scores of the control and treatment groups by the standard deviation of the control group.

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An effect size of 0.64 indicates that approximately 74 percent of the students in the control group lie below the average of the treatment group. When the differences in SAT scores were taken into account and the scores adjusted accordingly, the effect size indicated that about 71 percent of the students in the control group lie below the average of the treatment group.

The success rate was defined as the number of students who earned a grade of C or higher divided by the total number of students enrolled, including those who withdrew or did not receive grades. The success level for the PLTL students was significantly greater than that of the students in the traditional course, 77.0% versus 66.1% ($p < 0.01$). This means that approximately 25 more students per year were able to continue into the second semester of organic chemistry. The higher success rate is compatible with the lower withdrawal rate: 17.4 percent for the control group, 14.2 percent for the Workshop group. Workshop students earned a higher percentage of Bs and As (55% vs 45%).

Table 1. Student Performance in Organic Chemistry

Group	*n*	M, Total Points	SD
Control			
1992	233	445.5	124.7
1993	242	455.6	129.6
1994	297	513.1	124.4
Overall	772	474.7	129.7
Workshop			
1996	306	547.3	143.6
1997	284	564.6	129.6
1998	230	573.4	120.3
1999	217	547.2	132.2
Overall	1037	557.8	132.7

NOTE: Data reported are the year a course was offered; *n*, the number of students; M, the mean of the total points earned; SD, the standard deviation in the mean. Total possible points = 900, $p < 0.01$ for the difference in the overall means.

If broken down by gender or ethnicity, the results show that all PLTL groups outperformed their counterparts in the more traditional course by at least an effect size of 0.50. Thus there appears to be no bias based on gender or ethnicity.

Although we have not discussed the results of the Likert survey of the students and the interviews of the peer-leaders, these indicate a great deal of satisfaction with the Workshops. Moreover, the authors were able to identify factors that contributed to the success of students in the Workshops from these qualitative measures.

Summary

The research described here clearly suggests that the PLTL Workshops in the organic chemistry course studied both increased the level of student achievement and increased the retention of students in the course. The benefit appears to apply to all groups, regardless of gender or ethnicity. The authors' summary *(4)* speaks for itself:

> Workshop students earned significantly higher total points on exams which translated into higher course grades and demonstrated significantly higher retention rates compared with control recitation students. The attendance, survey, and interview data showed that students thought that the Workshop helped them learn organic chemistry; they found it socially engaging, intellectually stimulating, and, above all, a productive use of their time.

Although these studies were not be performed under ideal conditions, the consistency of the results generated by this and other studies indicate that PLTL Workshops do have a positive effect on student performance. Readers interested in further information about PLTL Workshops should consult the PLTL Web site at *http://www.pltl.org* (accessed Oct 2002).

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