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# Peer-Led Team Learning in Organic Chemistry: Effects on Student Performance, Success, and Persistence in the Course

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In the typical large-lecture course, instructors usually convey the content in an expository manner. At best, this course format provides instructors with the forum to present students with clear goals, reinforce textbook content, and generate new and expanded insights on the most important and challenging material that students need to master. However, the lecture is not the place where students actually come to grips with their tasks of mastering the new material effectively. For example, a common goal is to have students learn to solve problems on their own, a practice-intensive and time-consuming effort for which the lecture format can provide guidance yet relatively little direct assistance.

Acknowledging this, lecture courses typically have adjunct activities to guide problem solving. Homework problem sets, whether required or optional, are nearly universal in chemistry courses. Supplemental meeting times are common, ranging from required recitation sections to optional help sessions or open-office hours. Students frequently create their own accommodations for this purpose and set up study groups. Peer-led team learning (PLTL) is a structured setting for guiding student problem solving.

This study describes the PLTL program at Portland State University and analyzes its impact on the student experience in the organic chemistry course. Data have been collected for the past five years, comparing the students who selected workshops with those who did not; comparable data were also collected and analyzed for students from the same course during the year prior to initiation of the workshop program.

## Peer-Led Team Learning

At Portland State University (PSU), a concerted effort has been underway to improve student success in the first two years of chemistry — General Chemistry and Organic Chemistry, courses taught in large-lecture format. The courses are taught in a technology-rich lecture hall, and over the past several years a variety of innovations have been incorporated, including computer visualizations *(1, 2)* and animations *(3)*, ConcepTests *(4–6)*, course Web sites *(7)*, e-mail molecules *(8)*, and course management software (online quizzes and a discussion list on WebCT) *(9, 10)*. Starting in the 1999–2000 academic year, peer-led team learning (PLTL) was added (after all the other changes had already been incorporated into the courses).

The rationale behind PLTL and guidelines for implementation have been presented in detail *(11–13)*. In brief, PLTL provides a structured setting (usually called a workshop) to assist students in learning problem solving by working in small teams, under the guidance of a trained peer leader. The approach is constructivist, emphasizing the importance of discussion to help students create their understandings *(14)*. Each workshop is led by a peer leader (or mentor), a student who has successfully completed the same course recently and has been specifically trained for this role. A manual for training PLTL leaders has been published and is used as the basis for training at PSU *(15)*. Training is done in a day-and-a-half session just before the start of the fall term and continues throughout the year with weekly meetings *(16)*. Materials used in the workshop are provided by the instructor of the lecture course and are designed to address learning goals that are important for the course. The national PLTL project has sponsored several compilations of workshop materials for different courses *(17)*. Workshop materials used in the organic course at PSU have primarily come from these compilations, with some supplementation and reorganization to fit the schedule of our courses. Most of the organic workshop materials are available on the course Web sites *(7, 18)*.

At PSU, chemistry workshops are offered as one-credit courses, meeting for two hours each week and graded only on a pass–no pass basis. Expectations for a pass grade are regular attendance and active participation in the workshop activities. The workshops are optional and are restricted to students currently enrolled in the corresponding lecture course. We have accommodated all those who chose to enroll in the workshops by offering sufficient sections for about 40% of the lecture class. Section limits are stated as eight students, but we routinely allow up to ten (and occasionally more, depending on the ability and willingness of the peer leader). At PSU nearly 2000 students have been through the workshops and nearly 200 students have served as peer leaders, including both general chemistry and organic chemistry leaders.

The national PLTL project has tracked numerous examples of workshop students outperforming non-workshop students in a variety of different fields *(19)*. In the study most similar to this one, the University of Rochester has analyzed their PLTL program in organic chemistry *(20)*. Unlike our case, workshops are now a required component of the organic chemistry class at Rochester, and their comparison was with students in prior years with conventional recitation sections instead of workshops. Thus our data provide a different type of control group—a parallel rather than serial experiment; that is, all of our students were in the same class at the same time, although some had selected workshops and some not. Having the identical classroom experience is desirable for the control group, yet the lack of a random dispersion of the participants into the test and control groups makes the data more difficult to sort into cause and effect. In addition, the control group in our study engaged in no specific experiences for comparison with the workshop experience. We have tracked underlying differences in the two groups by their grade point averages (GPAs); the Rochester analysis used SAT scores. The improvements shown by workshop students at Rochester exceeded what might have been expected based on the underlying differences between the two groups, and we shall present evidence for the comparable conclusion. As pointed out in a recent analysis of the Rochester data *(21),* multiple experiments with consistent results lend credibility to a premise, even if each individual experiment may have flaws in its approach.

## Assessment Results

The success of the workshop program can be assessed in a variety of ways. Since the sections are optional, enrollment levels are a simple indication of whether students perceive the course to be a worthwhile addition to their busy schedule. Enrollments have held at a relatively constant fraction (about 30%) of the lecture course (and the courses have been growing in total population). Another means of assessing effectiveness is to ask the students their opinion about the value of the workshops. The national PLTL project provides a standard end-of-term questionnaire that has been used regularly *(22),* and we have also provided a course-specific survey. Students clearly believe that the workshops help them do better in class and improve their problem-solving abilities, particularly crediting interactions with the peer leader as well as interactions with their fellow students. A number of questions probe the individual's level of participation and interactivity; all indicate that students generally feel free to participate and value their own participation and that of others. Scores on this survey have been collected from a large number of institutions *(22)* and are consistent with those reported in the Supplemental Material.[W]

The real measure of success, however, must be determined by the extent to which the workshops increase student success and performance towards the course goals. We use three criteria to determine whether the workshops have had a positive impact:

1. *Student success*—for all those who begin the course, the number who pass with a grade of C– or better
2. *Student persistence*—for all those who begin the course in fall term, how many succeed (grades of C– or better) in all three terms in the same academic year
3. *Student performance*—for all those who receive final grades in the course, the percentage of the total possible points they accumulated

Table 1 summarizes five years of data with the workshops and includes the previous year as a reference, tabulating measures of student success and persistence. As indicated in Table 1, two instructors taught the same full-year organic chemistry course (the author taught four of the years and

**Table 1. Student Success and Persistence in Organic Chemistry**

| Instruction Parameters | Numbers of Students | Workshop Enrollments | Course Enrollments | Number of Successes | Percentage Successful | Three-Term Successes | Persistence (%) |
|---|---|---|---|---|---|---|---|
| Non-Workshop Students | | | | | | | |
| 1998–1999[a] | 149 | ——— | 309 | 240 | 78 | 52 | 35 |
| 1999–2000[a] | 143 | ——— | 270 | 191 | 71 | 42 | 29 |
| 2000–2001[b] | 119 | ——— | 204 | 134 | 66 | 26 | 22 |
| 2001–2002[a] | 124 | ——— | 239 | 148 | 62 | 30 | 24 |
| 2002–2003[b] | 154 | ——— | 291 | 185 | 64 | 40 | 26 |
| 2003–2004[a] | 149 | ——— | 291 | 210 | 72 | 42 | 28 |
| Totals | 838 | ——— | 1604 | 1108 | 69 | 232 | 28 |
| Workshop Students | | | | | | | |
| 1999–2000[a] | 61 | 112 | 155 | 136 | 88 | 36 | 59 |
| 2000–2001[b] | 67 | 110 | 161 | 131 | 81 | 32 | 48 |
| 2001–2002[a] | 89 | 169 | 225 | 188 | 84 | 50 | 56 |
| 2002–2003[b] | 89 | 162 | 223 | 178 | 80 | 45 | 51 |
| 2003–2004[a] | 129 | 243 | 336 | 306 | 91 | 86 | 67 |
| Totals | 435 | 796 | 1100 | 939 | 85 | 249 | 57 |

[a]Instructor was Wamser; [b]Instructor was Lutz.

Raymond Lutz taught two of the years) for which data were collected; in every case the same instructor stayed with the course for the full year, although the author was always the primary coordinator of the workshops. The non-workshop totals in the table represent the number of different students who enrolled in any one or more of the three organic courses that year and did not enroll in a workshop for *any* term. Enrollments represent the total number of terms of the organic course enrolled in by all of those students in that academic year (1, 2, or 3 per student). A success is defined as a course enrollment that ends with a grade of C– or better; recorded grades of D, F, W, X, I, or any other administrative grade were deemed unsuccessful. Three-term successes are defined as students who took all three terms of the course successfully in that year; persistence is the corresponding percentage relative to the total number of students. The table also reports the same data as applied to students who took one or more workshops during the year.

The data in Table 1 indicate that workshop students are significantly more successful in the course than those who do not choose workshops: their success rate is 85% compared to 69%. Considering the unsuccessful rates (15% vs 31%), workshop students could be considered only half as likely to end up with an unsatisfactory grade. The persistence rate for workshop students is also substantially higher (57% vs 28%), with workshop students twice as likely to complete all three terms. Application of a $Z$-test results in differences that are statistically significant (for success, $Z = -10.37$, $p < 0.01$; for persistence, $Z = -10.44$, $p < 0.01$).

Student performance data corroborate the positive outcomes seen in the student success and persistence data of Table 1; every year, performance averages for workshop students were consistently higher than those of non-workshop students. Averaged over the five-year period, coursework performance was higher for workshop students (71% vs 65%), corresponding to a course GPA 0.39 units higher (2.90 vs 2.51, where C+ = 2.3, B– = 2.7, and B = 3.0). As an independent indicator of student performance, the ACS Organic Exam is given as the final exam every spring. Average student scores on this exam are correspondingly higher for workshop students (80th percentile vs 72nd percentile). The 1998 version of the ACS Organic Chemistry Exam was used through 2002, and the 2002 version was used in 2003 and 2004. In 2002, the confidentiality of the 1998 version was breached *(23),* and student scores were unusually high (93rd percentile and 85th percentile, for workshop and non-workshop students, respectively). Excluding the 2002 data, average percentile scores for workshop and non-workshop students were at the 77th percentile and 69th percentile, respectively.[1]

Course performance was also analyzed as a function of other variables, including term, year, instructor, and gender. Instructor was a factor, with Wamser giving grades that averaged 3% higher than Lutz (68% vs 65%). The overall GPA of the students who enrolled with each of the two instructors was insignificantly different (3.16 vs 3.15, $n$ = 1616 and 757), and the course content was essentially identical in terms of textbook used throughout these years *(24a, 24b)* as well as the instructors' general approach in lecture (both Caltech grads with a physical organic, mechanistic emphasis).

The small difference is probably caused by slightly different approaches to grading (exam grading is always done with partial credit). In addition, Wamser's course offered optional extra credit assignments that could add a maximum of 3% to a student's grade; most students did most of the assignments *(8)*, and this component alone could account for much of the difference. Course performance also differed by term, with winter term a low point and spring term a high point (fall, 66%, $n$ = 969; winter, 65%, $n$ = 765; spring, 70%, $n$ = 638). This is likely due to the difficulty and amount of the course material in winter term, and the relatively familiar and popular material (bio-organic) taught in spring term. Considered in aggregate, males and females had similar course grade averages (males, 67.2%, $n$ = 1108; females, 66.7%, $n$ = 1259). Females were more likely to enroll in workshops ($n$ = 420, or 33%) than males ($n$ = 317, or 29%), yet both genders gained about 7% in course performance from workshop enrollment compared to their non-workshop counterparts (males, 72% vs 65%; females, 71% vs 64%).

## Correlation of Student Course Performance with Overall Grade Point Average

A significant complicating factor in analyzing the course performance data is the students' individual role in self-selecting themselves into the workshops—the test and control groups were not randomly determined. In addition, non-workshop students did not engage in any specific activities for comparison with the workshop experience. Simply browsing the wide range of grades obtained by the students who selected workshops gives the impression that there are both strong students (seeking an advantage for the best possible grades), as well as weak students (seeking an advantage just to make it through the course). Motivation is crucial in succeeding in a course as challenging as organic chemistry, yet quantifying such individual internal factors is difficult, to say the least.

As an attempt to generate additional insight into the characteristics of the student populations that self-selected into the workshops as well as differences in the student populations in the different years, we used their overall GPA as an indicator of how successful they had been in other coursework. The values used were for all courses the students had taken at Portland State University, collected at the time of their enrollment in the course under consideration. In this case, workshop students did in fact hold a higher GPA than non-workshop students (3.26 vs 3.14). However, the difference (0.12 units) is substantially less than the difference in course grades (0.39 in the same GPA units—2.90 vs 2.51). It is not uncommon for students to achieve a lower grade in organic chemistry than they may have earned in other courses. In this case, workshop students obtained grades in organic chemistry that average 0.36 units lower than their overall GPA (2.90 vs 3.26), while non-workshop students obtained grades 0.63 units lower than their overall GPA (2.51 vs 3.14).

While average values indicate the magnitude of the differences between the two populations, averages hide the immense range of student scores and GPAs. Another approach is to plot course performance vs GPA—effectively comparing students with the same overall GPAs with one another.

The plot in Figure 1 illustrates the wide range observed. The data shown are for just the 2003–2004 academic year (592 points: 235 workshop and 357 non-workshop students); the plot with data from all five years (2367 points) is too crowded to be helpful, although it shows the same correlations. The primary impression from Figure 1 is the broad scatter in the data. Nevertheless, the trends are distinctly different for workshop and non-workshop students.

A simple linear correlation of the data gives the two trend lines shown on the graph. For workshop students, performance *P*, expressed in percent, is calculated as:

$$P = 18 \times (\text{GPA}) + 14$$

where $n = 235$, and $R^2 = 0.62$. For non-workshop students, *P*, expressed in percent, is calculated as:

$$P = 22 \times (\text{GPA}) + 0$$

where $n = 357$, and $R^2 = 0.57$.

Simple linear correlations are reasonably consistent from year to year, with workshop students performing better than non-workshop students at nearly all grade levels. In general, the slopes are higher for the non-workshop students, indicating that students with lower GPAs get more out of the workshops. For example, a student with a 2.0 GPA will get on average 46% if enrolled in workshop and 41% if not enrolled. The average benefit diminishes for students starting with higher GPAs (a 4.0 student will get on average 87% if enrolled in workshops and 86% if not enrolled). However, treated as an incremental amount, the average 2.0 student gains 5% (out of a maximum possible improvement of 59%), while a 4.0 student gains 1% (out of a maximum possible improvement of 14%); these values are relatively consistent across the GPA range, varying 7–11% of the possible improvement to be gained.

A more complete statistical analysis (SAS Program, general linear model) studied the variability of a student's course grade with various parameters: workshop enrollment, overall GPA, gender, instructor, term, and year. Fitting the course grade as a function of these various parameters in different combinations using ANOVA (SAS Program, linear regression model) led to a variety of possible functional forms. The only form in which all parameters were significant ($p < 0.01$) was the following linear model:

$$\text{Course grade } (P) = a + b\,(\text{GPA}) + c\,(\text{workshop}) + d\,(\text{gender}) + e\,(\text{instructor})$$

Values for the various parameters were:

$$a = -5.96\ (\pm\ 1.27);\ b = 21.75\ (\pm\ 0.38);$$
$$c = 4.28\ (\pm\ 0.49);\ d = 1.94\ (\pm\ 0.46);\ \text{e} = 2.84\ (\pm\ 0.49)$$

An interpretation of this form is that the various parameters all affect a student's course performance (percentage of total points) in a statistically significant and positive sense, starting from an intercept of –5.96. Each unit of overall GPA correlates with 21.75 additional points in the course grade, being enrolled in the workshop is worth 4.28 points, being male is worth 1.94 points, and having Wamser as instructor is worth 2.84 points. Other functional forms give similar, although often quantitatively different, results. For example, a form using only GPA and workshop assigns over 8 points to the workshop effect.

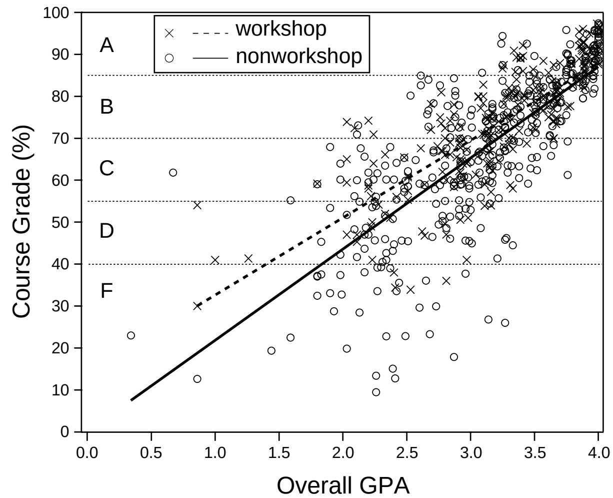


Figure 1. Plot of the correlation of student course performance (course grades) versus overall grade point average for students enrolled in the workshop (x) and students not taking the workshop (o) during the academic year 2003–2004. Lines represent the linear regression of the workshop data (dashed line) and the nonworkshop data (solid line).

## Conclusions

This study compares a self-selected group of workshop students with a control group of students who elected not to enroll in workshops. As a comparative study, there are two major causes for concern: the self-selection of the test group and the lack of control over the experience of the non-workshop group. The issue of self-selection was addressed by comparing students based on their GPA in all other courses; the differences between the groups and the effects of the workshop experience for the two groups are judged to be statistically significant. The more difficult issue is to understand what the workshop experience is being compared with. Workshop students engage in an extra two hours per week in structured problem-solving activities, plus presumably some additional time in preparation or follow-up work. Non-workshop students presumably study for the course as they ordinarily would, and the extra two hours they have available per week may be spent in a wide variety of ways, both relevant and irrelevant to the course in question.

The workshop materials are posted on the course Web site, so all students have access to them *(7)*. Thus a conscientious non-workshop student could access and work with the materials in a non-structured way, however it is impossible to gauge the extent to which this occurs. Thus this study can only claim to compare a workshop experience with whatever a student might choose to spend two hours per week doing. In comparison, the study of PLTL in organic chemistry at the University of Rochester could explicitly contrast student outcomes as a function of workshop enrollment with student outcomes of attending conventional recitation sections, since one or the other of those modes was always a course requirement *(20)*. Those results are similar to ours, concluding that the workshop experience improved student performance.

Despite these limitations as a case study, in all of the measures selected for study, students who elected to take the workshops outperformed those who did not take workshops: success rate in the course (85% vs 69%), three-term persistence (57% vs 28%), and course performance (71% vs 65%, course GPA of 2.90 vs 2.51, ACS exam scores at the 77th vs 69th percentile). Student attitudes towards the workshops were very positive and suggest some of the underlying causes of the gains.

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## [W]Supplemental Material

A number of tables providing additional data about the workshops, the student participants, and student performance are available in this issue of *JCE Online*.

## Note

1. For reference, a difference of 8 percentile points corresponds to about three additional questions correct: average scores were 51 vs 48 correct out of 70 questions total *(23)*.

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