

Sustaining change in upper level courses: peer-led workshops in organic chemistry and biochemistry

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Our peer-led collaborative learning groups, called Workshops, have now had extended success in two upper-level courses in chemistry and biochemistry. These Workshops are in turn supported by a third upper-level course for training peer-leaders. Our data confirm that the initial positive results from the introduction of Workshops in organic chemistry and in biochemistry have been maintained over time and over changes in course instructor. In addition, training upper-level Workshop leaders has contributed substantially to the self-sustaining character of our program. These longitudinal results have been accompanied by the lateral spread of Workshops into other courses and departments. The concurrent development of mutually reinforcing partnerships among faculty, staff and students has supported these changes. Complementary adjustments in institutional practice, and the recent establishment here of a Center for Workshop Education now provide a formal framework to foster the continuing promise of our Workshop program.

Keywords: active learning, peer-led workshops, peer-leader training, sustainable reform, STEM courses,

Introduction

Creative innovations in undergraduate education are not uncommon, but their survival is (Brainard, 2007). For long-term success, there are at least two requirements: (1) the innovations must be pedagogically sound and lead to improved student performance and learning, and (2) they must be sustainable within their own academic context. A classic example of an ultimately unsuccessful reform is the Keller 'PSI' (Personalized System of Instruction) plan for self-paced, mastery learning that was introduced in the late 1960s and adopted with enthusiasm through the 1970s. In spite of a solid grounding in learning theory, an enthusiastic reception from students and faculty, and a positive impact on exam performances and retention, the innovation was not sustained (Cracolice and Roth, 1996). An innovation with similar strengths is the incorporation of peer-led collaborative learning groups as an 'active learning' component of undergraduate lecture courses (Gosser *et al.*, 2001; Tien *et al.*, 2002; Platt *et al.*, 2003; Tien *et al.*, 2004). At the University of Rochester we have developed, implemented and maintained a program involving such groups, which we call Workshops, in two upper-level chemistry and biochemistry courses. This program now appears to be self-sustaining, and we will outline its origins and the development of a network of interactions, including other Workshop courses, that we believe has contributed to its viability.

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Background

Our work with problem solving groups began in 1990, when one of the authors (VR) started a few student-led study groups for some of the students in math and science courses. Participation in the weekly hour-long sessions was voluntary. Student leaders for these groups were selected based on their previous success in the course, for their interpersonal skills, and often for their interest in an academic career. These peer leaders were charged with facilitating the students' own on-the-spot problem solving rather than repeating the course lecture or running Q&A sessions about homework. In response to the challenges faced by the leaders, credit-bearing courses were developed in our learning center to train and support these student facilitators.

In 1995 another of our authors (JAK) began an ongoing collaboration with the national peer-led team learning (PLTL) project to develop and implement the peer-led Workshop in organic chemistry. The Workshop replaced the traditional graduate student-led recitation with a new structure that organized the students in the lecture course into small teams that provided "an active learning environment for students, [and] an appropriate leadership role for undergraduates" (Gosser *et al.*, 2001). This model upgraded the study group format by establishing a partnership of faculty, education specialists, and student peers working together to help all the students in the course construct conceptual understanding and develop problem-solving skills. In 2000, a second upper-level Workshop course was developed in biochemistry (TP). The leader training courses continue to be core components of our program, and we use the term 'Workshop' to refer to

Table 1 Success rates in CHM 203 (organic chemistry) over the past 15 years. The % success is the percent of students who earned a C- or better. The same instructor taught the course from 1992-2004; a new instructor took over CHM 203 in 2005

Year	% Success	Type of session
1992-1994	66	Recitation sessions
1995	66	Recitation sessions
1995	82	Workshop sessions
1996-1999	77	"
2000	75	"
2001	75	"
2002	78	"
2003	79	"
2004	75	"
2005	76	"
2006	81	"
2007	82	"

courses that incorporate this credit-bearing link between the leaders and their training.

In the sections that follow, we first describe the characteristics of two upper-level Workshop courses in organic chemistry and biochemistry, and their companion leader training courses. We present evidence that the pedagogical effectiveness of the courses remains as high as when they were introduced and that the initiatives are manageable, robust and appear to be sustainable. By the latter term, we imply both acceptance by the institution and long-term maintenance of the program. The overall Workshop program continues to propagate longitudinally and laterally within and across departments. Finally, we describe the various components of the program, and how they have been developed and integrated to be mutually reinforcing and possibly self-sustaining. This network of interactions has strengthened the Workshop program both academically and institutionally.

Course one: organic chemistry

The peer-led Workshop was introduced to Rochester in CHM 203, the first semester of a year-long organic chemistry course with an enrollment of 350 students, most of whom were second years. The traditional format of this course included three 50 minute lectures/week, homework problems from the text and standard 90-minute recitation sessions of approximately 20-25 students, led by graduate teaching assistants. In 1995, students were given the choice of participating in a recitation session or in a new structure called Workshop. The subsequent exam performance of the two groups was tracked and compared; the Workshop students outscored the recitation students by a statistically significant margin. Furthermore, the Workshop students expressed great enthusiasm for the new format. As a result, recitations were discontinued and all the students were assigned to Workshops from 1996 onwards (Tien *et al.*, 2002).

Exam performance in the traditional (recitation) format from 1992-1994 was compared to exam performance in the Workshop format in the period 1996-1999. In brief, the

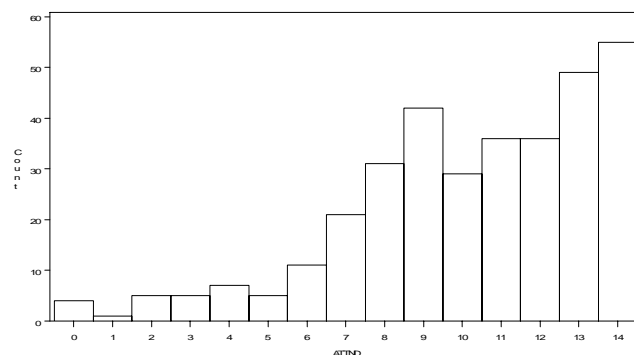


Fig. 1 Histogram of workshop attendance for workshops in organic chemistry (2006). The abscissa represents the number of Workshops attended (out of 14); the ordinate is the number of students who attended the indicated number of Workshops.

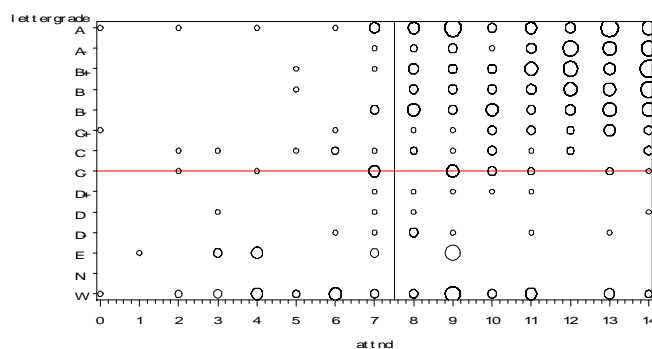


Fig. 2 Bubble-chart of grade vs. workshop attendance in organic chemistry (2006). In this chart, the bubble size is proportional to the number of observations. The lines at attendance = 7 and grade = C- divide the graph into four quadrants.

Workshop students earned noticeably better grades, resulting in a significant increase in the average success rate from 66% in the recitation years to 77% in the Workshop years. These results and others about attendance at organic chemistry Workshops and student attitudes and perspectives at the University of Rochester have been reported in detail (Tien *et al.*, 2002) and subsequently reviewed (Lyle and Robinson, 2003). Similar outcomes have been obtained for the organic chemistry course at Portland State University (Wamser, 2006). The increased success rate at Rochester has now been sustained for eight subsequent years and across a change in instructor after year five (Table 1).

All students are assigned to Workshops in CHM 203 and encouraged to attend, but the attendance is unforced in the sense that neither points nor credits are awarded for participating. Unlike our experience with recitation sessions, most students attend most of the Workshops. The average number of Workshops attended in 2006 was 10.2/14, comparable to attendance from 1996-1999, 10.3/13. Figure 1 shows the pattern of CHM 203 Workshop attendance in 2006.

Figure 2 and Table 2 report correlations of course grades with the number of Workshops attended for that same year. The top right quadrant of Figure 2 illustrates the strong

Table 2 Logistic regressions testing for dependent variable C– or better in organic chemistry (2006). In this analysis, the dependent variable is dichotomous, taking values of 0 (<C–, including attrition) or 1 (C– or better; success)

Independent variables	Beta coefficient	Standard error	P-Value
Workshop attendance	0.305**	0.054	<.0001
Gender (1=female;0=male)	-0.446	0.3389	0.1885
Minority	-1.054*	0.5152	0.0407
Constant	-1.618	1.8676	0.3863
SAT score (Prior ability)	0.0004	0.00137	0.7621
N	289		
% correctly predicted	76.4		

**Significant at the 0.01 level; *significant at the 0.05 level.

positive association between attendance and grade. In contrast, there are few students with low attendance and high grades (upper left quadrant) or high attendance and low grades (lower right quadrant).

Table 2 gives the results of a logistic regression of Workshop attendance in 2006 against the dependent variable ‘C– or better’. The analysis shows that Workshop attendance is significantly related to the probability of earning a C– or better, and the other variables are not.

These data support the hypothesis that Workshop attendance makes a difference in the grades students receive. Other interpretations are possible, and the correlation need not be causal; for example, good grades may simply result from increased ‘time on task’, or that the good (and conscientious) students go to Workshop. Whatever the reason, the average annual attendance at more than 70% of the Workshops has been sustained for the past 12 years. While this may not be the actual cause of the Workshop program’s success, it is arguably a necessary condition for sustainable change.

Course two: biochemistry

In contrast to organic chemistry, Workshop students in biochemistry were rewarded with 20 points/Workshop attended, above and beyond exam performance, toward their final grade out of 800 points (600 for exams and 200 for attendance at the 10 Workshops). Workshop attendance was very high, most likely due to the incentive of attendance points. In practice, the average attendance was 9.1 (s.d. 1.9, n=197) out of a total of 10 workshops. Alternatively stated, 81% of the students attended 9 or 10 of the available workshops.

Based on analysis of a biochemistry class in the fall of 2001, with 120 students enrolled, we found that attendance at Workshops correlated with students’ total exam scores in the course (600 points possible), corresponding to about 18 points per Workshop (Platt *et al.*, 2003). This is a correlative statement, not a causative one; we could not rule out that low scores and low Workshop attendance were due to disinterest, for example. Analysis of the impact of Workshops excludes ‘attendance points’; hence, the correlation represents the predicted ‘added value’ of each

Table 3 Maintenance of workshop impact over time and instructor changes in biochemistry. Data in the 2001 column have been previously published (Platt, 2003).

Year	2001	2005	2006
No. of Students	120	132	197
Male:Female %	48:52	53:47	55:45
Attendance mean (s.d.)	9.6 (0.8)	9.6 (1.2)	9.1 (1.9)
Predicted pts./Workshop (s.e.)	17.7 (9.6)	16.9 (8.7)	13.0 (5.4)

Standard error is indicated by s.e.

Workshop to examination performance. Thus “a student who attended all 10 workshops rather than just 6 would be predicted to score more than 70 points higher overall” (Platt *et al.*, 2003).

Others have reported that cooperative learning approaches in biochemistry offer benefits over the lecture approach (Anderson *et al.*, 2005), but long-term analyses have not been carried out. To determine whether the impact of Workshops seen in the 2001 course was maintained over time and how it might be affected by faculty transitions, we analyzed data obtained from iterations of the course in 2005 and 2006 (Table 3).

As in our previous analysis, we used an Ordinary Least Squares (OLS) analysis on the data, representing Total Exam Score as the dependent variable (‘attendance points’ are excluded). The predicted ‘added value’ of each additional Workshop in 2005 and 2006 is similar to that observed in 2001, indicating sustainability in the impact of the Workshop. In these two years two different faculty members (from the Chemistry department in ‘05 and from Biology in ‘06) co-taught with one of us (TP) on a 50:50 basis in the lecture component and in the preparation of examinations. Thus the Workshops, which remained relatively unchanged in content and format, contributed to improvement on exams prepared in part by other faculty members on their own lecture material, although the broad outline of the syllabus was little changed. Table 3 also shows steady large increases in enrollment that have continued in 2007 (260 students) and 2008 (306 students) and cannot be accounted for entirely by the yearly increases in the student population. As reported by enthusiastic students in biochemistry, the Workshop makes traditionally difficult material more accessible; this may account for some of the growth. From the faculty perspective, Workshops provide a mechanism to cope with increasing class size without sacrificing instructional quality.

Course three: a partnership in leader training

A third category of upper-level course, ‘Issues in Study Group Leadership’, is integral to the success of the courses in chemistry and biochemistry, and to their self-sustaining character. These two-credit courses are co-taught by learning specialists in partnership with the faculty instructors and are discipline specific. The peer leaders are required to enroll in the cognate course concurrently with their efforts as Workshop leaders. The content of these courses ranges from practical classroom knowledge to

theoretical pedagogical concepts, as the leaders develop new ideas about learning and practice the upcoming Workshop problems (Roth *et al.*, 2001; Platt *et al.*, 2003; Tien *et al.*, 2004).

The leader:student ratio in our Workshops is from 1:8 to 1:10, so about 10% of the students in organic chemistry (where each leader facilitates one Workshop/week) and 5% of the biochemistry students (where each leader usually facilitates two Workshops/week) will subsequently become trained Workshop leaders in the following year. Since 1995, a total of 400-500 upper-level undergraduate students have been trained to be peer leaders in organic chemistry or biochemistry. From 2000-2007, 35% of the chemistry majors graduated with peer leader training and experience. The leader training course contributes to the general education of these students as well as to their understanding of the specific subjects. In particular, it offers deliberate exposure and instruction in how students learn, thereby increasing the potential of the peer-leaders as both learners and teachers. The peer leader training course also contributes to the general education of the faculty by affording them an opportunity to engage with the research literature in education and a mechanism to learn the Workshop model.

The benefits of peer-leadership (Tenney and Houck, 2004; Tien *et al.*, 2004; Micari *et al.*, 2006; Gafney and Varma-Nelson, 2007) are recognized by students, and they compete for the available positions. In a typical year, the applicant:position ratio is 1.5:1 to 2:1. Some students serve as leaders in several different semester courses during their final college years. In formal recognition of the value of these and related experiences that match formal training to leadership practice (*e.g.*, serving as a trained resident advisor), the college awards a Citation for Achievement in College Leadership that is recorded on the transcript for students who have completed three different leadership experiences. From 2004, when this citation was first given, to 2007, 21 students graduated with this citation; together they served as peer leaders in Workshops for 46 semesters, averaging 2.2 Workshop courses each.

Discussion and conclusions

As Attewell (1992) characterizes institutionalization, "*The organization learns only insofar as individual insights and skills become embodied in organizational routines, practices, and beliefs that outlast the presence of the originating individual*" (p. 6). Although it is too soon to claim permanent change at Rochester, there are reasons to be optimistic. We have sustained the positive impact of the peer-led Workshops on student performance for a number of years beyond the initial successes in upper-level courses in organic chemistry and biochemistry (Tables 1 and 3). Since performance is a coin of the realm, student improvement in total exam points in Workshop-associated courses caught the attention of faculty, students and administrators. In practice, these three groups also paid particular attention to student testimony and enthusiasm. The continuing high level of unforced participation in the organic chemistry

Workshops, as reported in Figs. 1 and 2, provided compelling evidence that students value the Workshops; they are literally voting with their feet. Students talk to other students, of course, as well as to faculty and administrators, and their voices, added to those of the peer leaders, played a major role in building continuing support. As word spread, a spontaneous network of interest that transcended the individual courses began to grow. This was particularly crucial in obtaining budget increases for peer leader stipends and money, and time for staff from our learning center to co-teach the leader training course.

The organic chemistry and biochemistry courses do not stand in isolation. In addition to the longitudinal continuity of these two Workshop programs, significant lateral propagation of the model continues. After a gestation period of two to three years, the model was adopted in the second semester of the organic chemistry course, in first-year biology and in the general physics course elected by most pre-medical students in their third or fourth years. In each of these cases, peer-leaders from the organic chemistry course lobbied the faculty to add Workshops to the other courses. As the campus culture has changed, additional faculty have adopted the Workshop model for their own courses. Among these is another upper level course, in Quantum Chemistry.

Fifteen to twenty Workshop semester courses with accompanying leader training courses will be offered in 2008-2009 in eight departments; approximately 250 peer leaders will facilitate the interactions of about 2500 Workshop students. The partnerships that have supported this growth of Workshop courses are important ingredients of change because they link to the University community in different ways, building a robust, multi-dimensional structure of support. For example, the propagation of the Workshop model to other departments probably could not have been accomplished by a chemistry faculty member. The collaboration of faculty, educational specialists from the learning center and peer leaders is, of course, the central organizing principle in the peer-led Workshop program (Gosser *et al.*, 2001). The weekly meeting of the leader training course is the most visible expression of this partnership and the mechanism for building a team that is dedicated to helping students learn. The Chemistry Department now cross-lists this course, 'Issues in Group Leadership in Chemistry', with a Chemistry prefix, as one of the department's courses.

Under the leadership of a physics professor, another pillar of support developed in 2001 to respond to the lateral propagation of the model. This self-titled 'Workshop Task Force', an informal partnership of faculty and learning specialists, meets biweekly for much of the year and plays several roles. Our meetings provide opportunities to share ideas and know-how about implementing and sustaining peer-led Workshops in various courses. A continuing membership of experienced Workshop faculty and staff also functions as a support group for potential implementers of the model; such a core of early adopters reduces the uncertainty inherent in introducing change (Burkhardt and

Brass, 1990). As the name implies, the Task Force group works to solve common problems and develop new initiatives. For example, the Citation for Achievement in College Leadership originated in a discussion about the extraordinary contributions and accomplishments of our Workshop leaders.

Recurring problems obtaining and scheduling rooms for Workshops ultimately led to agreements with the Registrar to schedule times and dedicate space. The multiple connections of the members of the Task Force provide a network for ideas to become widely disseminated. Librarians want students in their libraries, and the science library recently took the initiative to create two dedicated Workshop rooms. In connection with a major restructuring project, the main library staff incorporated student discussions and opinion into their planning, resulting in a variety of arrangements for informal group study (Foster and Gibbons, 2007).

Two other dimensions of the university context are important. The institution understands the power of the research group, and faculty and students connect readily to the idea that the Workshop is a 'group meeting for undergraduates'. In addition, the Rochester curriculum emphasizes choice, participation, and intellectual responsibility. The central idea that Workshop is a place for students to explain, discuss and negotiate their understanding of concepts and ideas and learn to make up their own minds is a good fit with the goals of the curriculum. Formal recognition of participating faculty and learning specialists also helps propagate the model; all three authors, in fact, have received university or student-voted awards for their efforts in the Workshop program.

In summary, we have sustained significant change in teaching and learning in high profile, high enrollment upper-level courses in organic chemistry and biochemistry across time and variations in Deans, department chairs and course instructors. These long term changes include: (1) continuing effectiveness, (2) semester-long credit-bearing leader training courses, (3) formal diploma recognition for peer-leaders, (4) self-generated commitment from peer-leaders, (5) scheduled rooms dedicated to Workshop activities, (6) reliable budget support for the program, (7) enthusiastic participation from students, (8) lateral propagation within and across departments, and finally (9) evolution of the informal Workshop Task Force group into an instrument for change. As a capstone to these changes, the College is currently establishing a Center for Workshop Education in recognition of the success and sustainability of the Workshop program and to support its further integration into the fabric of undergraduate education at the University of Rochester.

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