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## *Problem-based Learning*

# An Innovative Selection and Training Program for Problem-based Learning (PBL) Workshop Leaders in Biochemistry*

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**We describe here a novel and effective structure to support the replacement of traditional recitation sections in a large upper level biochemistry course with small student-led problem-based learning (PBL) groups ("workshops") that employ a cooperative learning approach. This is part of an ongoing campus-wide effort to establish and maintain such workshops as a viable and integral component of many undergraduate courses at the University of Rochester. In biochemistry, for each workshop group of 8–10 students, we rely on a student leader, usually recruited from the previous year's pool of top students, whose function is both to guide and to inspire the group effort. A crucial component of our approach is that these leaders participate in a semester-long credit-bearing training course co-taught by the course instructors and an educational specialist. In this course, leaders review the preceding and upcoming weeks' workshops and study selected aspects of learning theory, group dynamics, and diversity training. Overall our workshop leaders feel that they benefit substantially from this training by improving their pedagogical skills in the context of biochemistry, by putting theories about group leadership and learning into practice, and by solidifying their working biochemical knowledge. We believe that the important features of implementing our model (the incorporation of a problem-based learning approach into a student-led small group format) are: 1) the teamwork as co-equals between the course instructors and the educational specialists, 2) the concurrent iterative training of the workshop leaders in a credit-bearing course of study, 3) the built-in leader turnover (normally a frustrating occurrence) as a beneficial component of the course, and 4) the enthusiasm and commitment to biochemistry displayed to current students by their peer leaders.**

*Keywords*: PBL workshops, peer-leader training, educational partnership, teaching biochemistry, upper level undergraduate courses.

At the University of Rochester over the past 3 years, we have replaced traditional weekly recitations in a large college level introductory biochemistry course with small cooperative learning groups. These "workshops," as we call them, employ a problem-based learning (PBL)[1] format with groups of 8–10 students meeting weekly for 2 h to solve descriptive biochemistry problems in a cooperative learning context. We have also found that the effectiveness of our workshops has been greatly improved by having a skilled leader present to facilitate inquiry and promote uniform participation in contrast to a "leaderless" PBL format that may be appropriate in other situations. There are a number of administrative and pedagogical challenges involved in this type of undertaking, not the least of which is the dual requirement for an increased number of leaders (both a recruitment and a budgetary hurdle) and the need for training that prepares leaders to facilitate workshops effectively. We describe here our solutions to these problems, which also yielded several positive consequences that we did not initially anticipate.

## THE CHALLENGE OF CONVERSION

Our traditional undergraduate introductory biochemistry course at the University of Rochester has had an enrollment of 100–150 students. To supplement the 50-min Monday/Wednesday/Friday lectures, each student in the earlier version of the course was encouraged to attend one 75-min recitation section during the week. These were designed to serve 20–25 students in a question/answer setting led by an undergraduate or graduate teaching assistant (TA) who might also offer a brief review of the lecture material. Although these TAs were paid for their semester of work, they did not receive formal training in teaching or group facilitation with the unspoken assumption that their previous coursework in biochemistry constituted sufficient preparation for this teaching role. Thus, in a typical semester, five TAs, each meeting weekly with 25 students, would be enough to staff all the recitation sections in the course. Although this met the needs of some

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[1] The abbreviations used are: PBL, problem-based learning; TA, teaching assistant.

students, for most it was another variation of a passive learning experience. From a course director's perspective, it was not very effective pedagogically, inciting neither curiosity nor involvement on the part of the students.

A variety of options that might improve student interest and learning outside of the lecture component of our biochemistry course have been mentioned in the literature [*e.g.* see Refs. 1–3]. We chose to build upon existing examples at the University of Rochester that have been successful in introductory courses at lower levels in biology, chemistry, physics, and computer science, for example [see Ref. 4]. A common feature of the workshops in these courses is the reliance on a small group format with a problem-based cooperative learning approach, utilizing a leader (or guide) with knowledge of both the subject matter and pedagogical techniques to facilitate group learning. This leader plays a crucial role in guiding group interactions as the students engage in the practical aspects of cooperative problem-solving. This includes trying to elicit and maintain a balance among the contributions from group members and posing questions to challenge their thinking without providing the correct answers; in fact, the students themselves must validate their answers [5–7].

Upon choosing this format for our biochemistry course, we immediately faced a challenge: our targeted workshop group size of 8–10 and a class of 120 students meant a need for 12–15 leaders, and there were only three available pools from which they could be drawn. Recruiting the 7–10 additional personnel from faculty ranks was not possible despite the advantages of knowledge, experience, and wisdom that faculty could bring to the task. Departmental graduate students were another possible source, but the available numbers (three to five at most) were far below the need, and those who do participate in teaching assignments find themselves in frequent conflict with their primary commitment to dissertation research.

The third pool to which we turned was undergraduates themselves, taking advantage of guidance in the literature as well as the on-campus experience of others in using peer leaders [5, 7, 8]. As it happened, when we invited students who had already succeeded in the course to participate, they were eager to volunteer and viewed very positively the opportunity of revisiting biochemistry while helping out others now taking the course. This, at least, solved the problems of motivation and having a sufficient pool of candidates. It did not, however, address the concern of entrusting workshop facilitation to undergraduate leaders who often had little prior teaching experience. Our task then became how to select appropriate potential leaders from the undergraduate pool and how to train them effectively so as to best develop their potential.

## CHOOSING AND TRAINING WORKSHOP LEADERS

In practice, we follow the guidelines of Roth *et al.* [6] to initiate leader selection. Near the end of the semester before the biochemistry course is offered, we send letters to the top 20% of the previous year's class inviting them to apply to be workshop leaders in the upcoming term. We review each application, which requests background information (courses and grades, experience, and other activities), a synopsis of career goals, and a statement as to why the individual wants to be a workshop leader. Although acceptance is not automatic, the volunteers have been of high quality, and for our biochemistry course their numbers have matched our needs fairly closely. Before the final selection, a meeting is held for all interested applicants in which we outline in detail the activities and duties of leaders in the course ahead. For those chosen, a formal contract is signed, committing both sides to these duties and monetary reimbursement for the semester's service.

The selected leaders are thus all highly motivated and have excelled academically in biochemistry. Nonetheless, in our experience, good leaders are made, not born, and training to serve as an effective workshop leader is essential [6]. A unique aspect of our program is the character of this training program itself. Based on previous experience, we knew that good preparation to be a workshop leader cannot be readily imparted in a brief crash course, however intensive. As with the skills of most good teachers, many of the skills of leading workshops are accumulated over time, and occasional failures are part of the learning process. To support good preparation most realistically, our training course for leaders extends across the entire semester during which the biochemistry course is given. It meets weekly for 90 min and is mandatory for all leaders. To validate this training and provide the leaders with a demonstrable benefit on their transcript, it is a formal college course entitled "Issues in Group Leadership," and two academic credits are earned upon successful completion.

The second unique and essential feature, in our view, is that the training course is taught by the faculty member(s) and educational specialist(s) as co-equals with both present at each session. Approximately half of every meeting is occupied with evaluation of past and upcoming workshop biochemical material, and the other half is occupied with pedagogical training and learning theory. Each week, therefore, the leaders come to their workshop groups primed not only with biochemical insights but with new understandings of how best to facilitate learning within the group. This iterative aspect of our training program has been especially rewarding as the leaders are reinforced by what works well and can return to the following week's training session to discuss how to modify what does not. These activities are further reinforced by two other requirements. First, each leader must keep a weekly journal in which observations and comments are recorded about how well both the biochemistry and the pedagogy are working. This serves as a record of growth and learning and has proved very useful in each leader's self-assessment. Second, each leader is required to carry out a self-directed project during the semester, relating theory to practice in any chosen aspect of small group cooperative learning; these projects are often done in groups of two or three leaders working together.

Our combined leader training arrangement truly unifies the training course and, by extension, cements the integration of the workshop component with the lecture material. Moreover, it is exceptionally valuable for any faculty member, who, often despite many years of teaching experience, may not be familiar with recent developments in

TABLE I

*Examples of "Leader Training Topics" covered in our one-semester, two-credit "Issues in Group Leadership" course presented concurrently with the lecture course and the workshop component*

| Sample topics in workshop leader training course | Sample weekly readings by topic |
|---|---|
| The role of the workshop leader, promoting teamwork and cooperative learning | V. Roth, G. Marcus, E. Goldstein (2001) Peer-led Team Learning: A Handbook for Team Leaders, Prentice-Hall, Inc., Upper Saddle River, NJ. |
| Metacognition | Hewson, P., "Teaching for Conceptual Change," D. Treagust, R. Duit, B. Fraser, Eds. (1996) Improving Teaching and Learning in Science and Mathematics, Teacher's College, New York. |
| Reciprocal questioning | A. King (1990) Enhancing peer interaction and learning in the classroom through reciprocal questioning, *Am. Educ. Res. J.* **27**, 664–687. |
| Learning styles | H. Gardner (2000) Intelligence Reframed: Multiple Intelligences for the 21st Century, Basic Books, New York. |
| Diversity issues in the workshop | S. Rosser (1997) Re-engineering Female Friendly Science, Teachers College Press, New York. |
| Student development | W. G. Perry (1968) Forms of Intellectual and Ethical Development in the College Years: A Scheme, Holt, New York. |
| Algorithmic vs. conceptual learning | M. B. Nakhleh (1993) Are our students conceptual thinkers or algorithmic problem solvers?, *J. Chem. Educ.* **70**, 52–55. |
| Motivation | E. Deci, P. Ryan (2000) Intrinsic and extrinsic motivations: classic definitions, new directions, *Contemp. Educ. Psychol.* **25**, 54–67. |

educational theory and now has the opportunity to see them applied. Our typical list of educational topics covered (Table I) includes explorations of learning styles, stages of learning, small group interactions, and diversity, topics with which many science faculty and students usually have had only superficial contact. These topics are first presented as assigned readings for each weekly theme and, in conjunction with the leader's journal and on-going practical experience, are designed to promote metacognition. These integrated attributes of the leader training program should clarify why it necessitates an entire semester and further highlight the benefits to faculty and leader trainees alike. On the other hand, the educational specialist also gains by first-hand exposure to the specific topical problems of biochemistry (in our case) and can thus more readily help adapt the learning tools and theory at the practical level.

In summary, we have found that the shared responsibility for academic expertise in both science and pedagogy strongly emphasizes and validates their interdependence. By the end of the semester, the leaders have begun to acquire an appreciation for the complexity of learning that is independent of the subject matter, and the teaching faculty have solidified their own working knowledge in these areas.

## LEADER TURNOVER: CURSE OR SOLUTION?

Although the use of talented and trained undergraduates as peer leaders provides surprisingly good solutions to some of the problems mentioned above, a substantial concern remains: college students move ahead yearly. Thus our training program, however excellent, has a built-in limitation, namely the departure of the leaders after a contribution of only one semester's duration, just as their effectiveness is being optimized. As it happens, the opportunity of having new student leaders each year, freshly trained, has had several unexpected benefits. First, the loss of leader experience each year is offset by the fresh enthusiasm of the new group, and they are closer to their student peers in both age and subject matter familiarity than the older group would have been. Second, the commitment of the new leaders to biochemistry and PBL workshops validates the value of the material in a way that faculty exhortations, however sincere and enthusiastic, cannot. Third, the best students in the class can see each week the value of the leadership position that they themselves might occupy the following year (*i.e.* automatic leader turnover encourages applications from the best current students with an interest in teaching and leadership). This contributes a self-sustaining character to the niche of being a workshop leader and is thus a great overall benefit. Fourth, with a leader:student ratio in each workshop of about 1:8, by graduation time the top 10–12% of the biochemistry class has also received significant training in how to lead and facilitate cooperative learning as well as accruing the benefits of revisiting biochemistry. Finally, each incoming group of new leaders is quite diverse and leads to a yearly evolution in the training course itself as we adapt to this diversity (*i.e.* we learn from each yearly experience about how to prepare leaders more effectively). In summary, workshop leader turnover enriches our biochemistry course and the accompanying training program and benefits a substantial fraction of the class in ways that will serve them well regardless of their future careers.

## ASSESSMENT

The use of PBL-styled small group workshops with trained student leaders as described here has been implemented for only 2 years in our undergraduate biochemistry course. Evaluation of the degree of its success is important, and we have outlined above some of the perceived qualitative and anecdotal positives of utilizing workshops as a substantial component of our course. It is still very much a work-in-progress, and a meaningful quantitative assessment is more difficult.

In the 1st year that workshops replaced recitations, the normalized bell curve of point scores was superimposable on the prior year's, except for a decrease in the third quartile and a corresponding shoulder on the high end of the second quartile. Many factors other than the workshops, however, might have contributed, and we are re-

TABLE II

*Ordinary least squares regression using total earned points (total possible = 600) as the dependent variable for BCH 250 for students who completed the course (Fall 2001)*

*B* represents the impact of a change in one unit in the independent variable on the value of the dependent variable. Here the value of *B* for workshop attendance is 17.7, *i.e.* a change of one unit (attendance decreasing by 1) reduces the total points by 17.7. The constant is the predicted value of our dependent variable when the value of our independent variables are all zero. It is the intercept of the regression line (*i.e.* where the line crosses the *y* axis). The *F* value (and its significance) is a measure of "goodness-of-fit" of the statistical model. A high (and statistically significant) value indicates that we can reject the hypothesis that all coefficients in our model are simultaneously equal to zero. The significant *F* test value of 3.13 indicates that we are not in the presence of a model where all variables are insignificant.

| Independent variable | *B* (standard error) |
|---|---|
| Workshop attendance | 17.7 (9.6)[a] |
| Gender (1=female, 0=male) | 17.3 (12.7) |
| Constant | 255.6 (92.7)[b] |
| *N* | 120 |
| Adjusted $R^2$ | 0.034 |
| *F* | 3.13[c] |

[a] Significant at the 0.10 level.
[b] Significant at the 0.01 level.
[c] Significant at the 0.05 level.

luctant to ascribe any specific cause to this shift (*e.g.* perhaps the lectures were simply better). In the 2nd year (Fall 2001), we had a 50% larger class and took another approach to assessment. We examined overall scores of all students completing the course ($n$ = 120), calculated before the workshop contribution (20 points/workshop for attendance and participation), and analyzed the relationship between workshop participation and overall performance in the course. Since the dependent variable is continuous (total points), we used the method of ordinary least squares to obtain a coefficient representing the impact of a change of one unit in the independent variable (number of workshops attended) on the value of the dependent variable. As Table II shows, there is a projected point advantage that corresponds to 17.7 points/workshop attended of the 600 total points available. Thus a student who attended all 10 workshops rather than just six would be predicted to score more than 70 points higher overall (exclusive of the 80-point gain for participating in four more workshops). This is a persuasive number and is statistically significant; however, we must note that this is simply a correlation and that students who failed to attend some workshops may include less motivated or interested individuals who do less well for reasons other than simply missing a particular workshop experience.

Additional evidence for beneficial results of our program comes from comments written by the workshop leaders themselves. For example, one remarks that "In contrast to recitations, the workshops I have participated in actively engage their students into the material presented. Instead of learning answers, I learned how to think to be able to solve the problems presented. I also found that by working in a group we could combine our knowledge to solve a problem that none of us working alone would be able to." Another leader says that, unlike the situation in many recitations, "I could see a visible progress in my understanding of the subject matter. This visible progress drew me to workshop quite willingly, rather than out of obligation . . . . Leading workshop and being trained in the leadership training course has opened my eyes to many aspects of learning. I learned how to facilitate understanding and problem solving through subtle guidance rather than straightforward lecturing. In conclusion, if I were to list the undergraduate experiences that have most deeply impacted me, I would have to put the biochemistry workshop program near the top."

These statements support our informal surveys of the class in which the students express a preference for workshops rather than recitations. In the longer term, as we gather more data that will average out disparities of individual class groups and are able to follow students through their subsequent graduate or professional training, we anticipate being able to make firmer statements about the value, both perceived and substantive, of our biochemistry workshops.

## CONCLUSIONS

In the process of incorporating an integrated PBL workshop component into a large upper level undergraduate biochemistry course, we have implemented an effective and successful program for obtaining, training, and maintaining the number and quality of workshop leaders necessary for the conversion from the previous recitation-based approach. Our new model is based on the finding that many good potential leaders are available among the cohort of students who performed well in the previous year's course and that, with a suitable training program, these individuals become excellent leaders. A crucial parameter of our model is the co-equal partnership between faculty and educational specialists that integrates techniques and theories of teaching and learning directly with the material to be presented in unified sessions; neither aspect is readily separable from the other nor given undue weight. Finally, an unanticipated but important discovery is the advantages that accrue from the yearly turnover of workshop leaders. Both in being more up-to-date in their biochemical knowledge (not a small advantage with today's rapid developments in this arena) and closer to those they lead in age and experience, they are extremely effective as role models and in validating biochemistry as an exciting and rewarding area of study.

The introduction of any of the three main aspects of our program would benefit a course converting to the workshop approach, but the overall combination has a synergistic effectiveness that goes far beyond the contributions from any single component. The use of enthusiastic but unseasoned recent graduates of the course as leaders is reminiscent of the early days of the United States Peace Corps where young college graduates were briefly trained and sent out to many countries around the world. Their impact abroad is well known, and the long range effects of their return to the United States have been significant (one of us, T. Platt, was in an early group of these teachers). Our extended training program running concurrently with the course is likewise an important aspect of the system in providing the nascent leaders with time for reflection, experimentation, and feedback to continually improve their

performance. Finally, the collaborative efforts of the faculty and the educational specialists as co-equals is really the capstone of our arrangement. We are continually surprised by the new insights and perspectives that emerge in our weekly training sessions, many of them contributed by the trainees themselves, who are unencumbered by prior dogmas.

In a broader view, the approach we have described here should be applicable to many kinds of courses from secondary through graduate or medical education. It requires only the availability of former students in the course, the willingness and resources to mount an effective leader training course, and the participation of knowledgeable and experienced educational specialists to work with faculty in a collaborative and complementary fashion. The approach also offers an effective practical bridge between traditional college lecture/recitation-based courses with large enrollments and the ideal espoused by some for conversion to a PBL format with few if any lectures.

In conclusion, we hope that our model will prove useful in many varied situations and believe that it has the adaptability to do so. At the University of Rochester, our course is only a small part of an extensive effort to develop and promulgate workshops throughout the college in a variety of disciplines, although the available styles and methods of implementation differ widely even on a single campus [4]. As we move collectively from traditional lectures toward combinations of on-line learning and small group PBL formats, the future of education offers truly intriguing possibilities.

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