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In the Classroom

Workshop Chemistry: Overcoming the Barriers to Student Success

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The message of the late 20th century is that chemists will have to work with skill and efficiency to attract support to their discipline.

Prevailing modes of instruction, often passive in nature, do not address crucial issues for student success in science: the need for students to become part of an intellectual community, the differences in the ways students learn, and the powerful role that mentoring can play in involving students in science. Furthermore, students who spend most of their instructional time listening to lectures seldom learn to communicate scientific ideas and to become part of a problem-solving team, skills that industry tells us are crucial to success in the workplace.

Workshop Chemistry is a peer-led team-learning model of instruction that provides an active learning experience for students, creates new leadership roles for those who have done well, and

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involves faculty in the process of reform. A modest reduction in lecture or recitation time is replaced by a two-hour student-directed small group problem-solving and model-building workshop.

The Workshop Chemistry Project is a coalition of faculty, learning specialists, and students from a variety of institutions organized around the theme of developing the workshop model as an integral part of the course structure. Several brief descriptions of the workshop courses offered in the Fall of 1995 are provided, along with some sample workshop problems. Surveys, focus groups, student logs, faculty interviews, and actual course results provide insight into the enhanced learning in the workshop and the progress of the project towards its goals.

I. Introduction

Everyone who teaches introductory chemistry classes knows how difficult it is to engage students with the material. We frequently lose students during these introductory course sequences; even many of those who finish the beginning courses in good standing later abandon the sciences.

The decision to drop out of the sciences, of course, is felt on an intensely personal level by individual students, but this falling away is not just a personal or local phenomenon. On the contrary, it is a problem of national scope [1], [2], [3]. Some may view this as a form of academic Darwinism, a beneficial way of locating those students who are the fittest for a career in science. Others are concerned about this problem, but find it difficult to overcome the enormous obstacles to change. These attitudes of apparent indifference or helplessness waste both resources and reputation; they are too expensive to be maintained. The message of the late 20th century is that chemists will have to work with skill and efficiency to attract support to their discipline. Some of that work begins in the classroom.

Chemistry teachers cannot afford to dismiss large segments of the student population. We need their talents in the field, and we also need their goodwill as students and, ultimately, as citizens. Tobias [1] defined one part of the problem; there is a group of capable students who are alienated by many aspects of traditional introductory science courses. Another group of students, for one reason or another, find it hard to learn chemistry. Many of these students are ultimately capable of doing good work, even though they are not ready to do so from the first day. We cannot afford to discard these students.

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We also face a compelling challenge to reinvent science education to help students to become better prepared for the modern technological workplace. We live in an information-communication age in which employers are calling for new skills. Our own survey conducted with industry presidents, vice-presidents, and research managers indicated that the attributes most desired, but least well prepared for in undergraduate education, were communication and team problem-solving skills (survey available upon request from City College). This is also the conclusion by the ACS Committee on Professional Training roundtable [4].

In response to these concerns, a coalition of faculty, learning specialists, and students from 14 colleges and universities has developed the Workshop Chemistry project around the unifying theme of peer-led team learning as a new model of instruction in chemistry. This model, which was initially developed at the City College of New York with support from the National Science Foundation, is derived from the conviction that learning chemistry requires students to participate in a creative, interactive learning environment. The members of the consortium have adapted the model to a wide variety of campuses: large urban commuter campuses, small liberal arts colleges, and private residential research universities. A list of the project partners is available in a separate file (projpart.pdf). We view meeting the following goals as our measures of the project's success:

- To improve student attitudes toward chemistry and the scientific enterprise in general.
- To increase students' mastery of chemistry concepts and problem solving skills.
- To increase students' ability to express scientific ideas and to work as a team, skills that are required in the workplace.
- To establish a culture that encourages curricular innovation with feedback from students, faculty, and industry.

The specifics of this project are outlined below, but we believe it is important first to define the problem more fully by examining the barriers to success. A good place to begin is at the same point our students do, with the problems they experience in becoming part of the community of learners on our campuses [5], [6]. The acclimation has two parts; making connections to other students is intuitively related to making connections with the academic work, but student isolation from the active intellectual engagement with others occurs in a variety of college environments. Students in a large urban commuter campus, such as the City University of New York, often hold part-time jobs, live at home,

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and have responsibilities outside the context of campus life. Under these conditions, it is difficult to form a collegial network of learners. Residential students, like most of those attending institutions such as the University of Rochester or St. Xavier, face the challenge of constructing a new home for themselves on campus, and dealing with the intrusions of their social worlds into their study space. The very stage at which first and second year students may most need to be part of a community of learners—when they are facing the steep learning curves of their introductory college science courses—is likely to be at a point in their lives when they are feeling the least integrated with a constructive learning environment on their campuses. So the tendency for many students is to go it alone, even though we know from the pedagogical literature that an exclusively solitary approach to studying science is less than optimal [7]. Solo study is often passive study, which fails to capture the approach to problem solving that we consider so crucial to scientific inquiry.

Another barrier to student engagement is the lack of recognition accorded to learning differences [8], [9]. Although many instructors recognize that students come to their courses with varying preparations and with varying constructs of chemical knowledge, few beginning science courses are designed to respond fully to differences among learning styles. Instead, we tend to teach via the channels that work for us. Those of us who are visual learners are likely to rely heavily on pictorial representations of the material; those who think best in quantitative terms tend to emphasize numbers and equations in their presentation of information, and so on. This cloning is not entirely without merit; it is a benefit to students to model the thought process of someone with expertise and success in the field. But, by emphasizing only certain learning styles, we inadvertently fail to connect with students who learn in different ways, and we may very well be cutting off the development of new perspectives on the problems in our field.

A third barrier for students is the difficulty in connecting with a mentor during these early stages of their college science work. The importance of mentoring relationships has been named as a major factor in students' involvement in science and their subsequent decision to choose a career in science [1], [10], [11], and is often noted in the context of faculty supervised student research projects. While these projects are excellent opportunities, they are usually available only to those students who have already succeeded in introductory courses. Those who made it through our beginning sequences often had to do this on their own, because the size of the enrollment in these courses and the mass of material that needs to be addressed lead to an impersonal classroom environment.

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The lecture method of teaching does not address these barriers to student success in science [1], [9]. In fact, it is often part of the problem. In the lecture hall, many students feel isolated from one another and find it difficult to become actively engaged with the subject at hand. The lecture model, with its emphasis on the transmission of information from faculty to student, leaves little room for the introduction of self-expression and student interaction. One of the most troubling findings is that many talented students abandon the sciences because they find the lecture format passive and impersonal. The impersonal lecture style also seems to reinforce myths about competition and survival in beginning science courses [1].

If we hope to change our introductory courses, the involvement of faculty is essential. Many of us, of course, have noted well these barriers to student success, but face obstacles of our own as we try to develop new learning environments. We have a limited amount of time to teach students the concepts and problem-solving skills of chemistry. It is difficult even to make regular eye contact with the large number of students in our sections, let alone to find the time to develop personal mentoring relationships with these students.

As we try to develop more effective, student-centered approaches to teaching, we find ourselves facing attitudinal barriers. Our colleagues may not appreciate the benefit of discussion and interaction in learning introductory chemistry. It is common for instructors to conceive of teaching as a one-directional exchange of non-debatable information. Confronted as they often are with a lack of student success, it is difficult for many to see how students could construct their own understanding of the material.

Another barrier to change is the reinforcement of the status quo by those students who do succeed within the current model of instruction. When instructors hear about new approaches, which are too frequently presented in an adversarial way, they can quite easily point to those “A” students who have flourished in their classes. The success of these students encourages instructors to continue things the way they are, utilizing the same methods over and over again.

II. The Workshop Model

Workshop Chemistry is a peer-led team learning model of chemistry instruction that was developed originally at The City College of The City University of New York as part of a project funded by the National Science Foundation [12]. The program was designed to respond to the high attrition rate in introductory chemistry courses, and was

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substantially influenced by the work of Uri Treisman [7]. The operational essence of the model uses student-led peer groups as an integral part of the teaching of the course. The conceptual essence of the model requires students to engage actively with each other and with the subject matter. Instructional materials are designed by the faculty to focus the group on the key issues and to be worked on and discussed by the group during the workshop session. The approach emphasizes the students' responsibility to construct their own understanding of the subject with the help of their peers and the guidance of the workshop leader.

Group size and membership

The basic model calls for groups of 6-8 students who meet together for guided chemistry study each week for two hours. We have found this group size to be optimal in a number of ways: it provides for a diversity of points of view, it is a manageable number for the student leaders, and it allows for productive group cohesion to develop. Groups of this size also can be divided in two or more subgroups for some exercises. Once established, groups soon coalesce and maintain their membership for the duration of the academic term. (Please see the Faculty Interviews section below for more information about group formats.)

In general, the groups are heterogeneous; as is recommended in the literature, there is no conscious attempt to separate students by ability [13], [15]. The two-hour timeframe has evolved through experience; we have observed that this time period allows for the kind of intense discussion and interaction that is the goal of the model. The addition of these workshops sometimes has required restructuring of class hours so as not to create a too-heavy time demand on students. We believe that the benefits of students' active participation in workshops can offset a modest reduction in lecture time.

Workshop leaders

Workshop Chemistry groups are led by undergraduates who have recently (and successfully) completed the course. In contrast to the traditional TA role, the leader is not expected to be an expert about the subject. Instead, the leader is a facilitator of the group discussion and a mentor and role model for the other students in the group. The training of peer leaders involves weekly meetings with faculty. The goal is to acquaint leaders in team

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learning skills, so that they themselves can provide alternatives to the lecture format. The training sessions also include reviews of the workshop materials, and offer a support mechanism that allows leaders to bring up problems that occur in their groups and to relay feedback about the course to the instructor. A sample syllabus is available in a separate file (trainsyl.pdf).

Materials

The workshop model calls for written guides for the group sessions. These guides incorporate elements of team learning, like positive interdependence and individual accountability, in a way that consciously promotes group interaction. Students are encouraged to work together to solve problems and to explain their reasoning to the rest of the group. Types of activities include problem solving, model building, and structured group discussion. More information about materials developed for our workshop program are available in a separate file (smplmatl.pdf)

- Sample Materials for General Chemistry, City College and New York City Technical College
- Sample Materials for Organic Chemistry, University of Rochester.

Sample Programs

Workshop Chemistry is still very much a work in progress, with project partners in many different stages of development. During Fall, 1995, there were 18 faculty members from 14 institutions working with 150 leaders with workshop courses that impacted 1500 students. More detailed descriptions of five selected courses within the project are avaialable in a separate file (courdes.pdf) that accompanies this article.

- General Chemistry, The City College of The City University of New York, Professor David Gosser
- Organic Chemistry, The University of Rochester, Professor Jack Kampmeier
- General Chemistry, New York City Technical School, Professor Victor Strozak
- Bridge to Chemistry, The City College of The City University of New York, Professor Stanley Radel
- Principles of Organic and Biochemistry, St. Xavier University, Professor Pratibha Varma-Nelson

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Results from Faculty Interviews, Focus Groups of Students and Workshop Leaders, Student Comments, and Leader Logs

We have included evaluation in the project from the beginning, so we have collected information that helps us understand the results of the project to date and directs our future plans. The project evaluator conducted the faculty interviews and the focus groups of students and workshop leaders. A cross-section of the faculty participating in the project was represented by the faculty interviews; City College students and workshop leaders were the members of the focus groups. The student comments were obtained via questionnaires distributed by instructors. The workshop leader logs were part of the training course at the University of Rochester.

Faculty interviews

In December, 1995, nine structured faculty interviews were conducted with professors who have taught courses as part of the Workshop Chemistry project. They represent a cross section of courses and a variety of stages of implementation of the workshop model. These professors have taught a total of more than 1000 workshop students, with class sizes ranging from 25 to 300. Their courses include General Chemistry, Allied Health Chemistry, and Organic Chemistry. Topics discussed in the interviews included the format of the workshop program, the training and ongoing interaction of the professors with the workshop leaders, problems in implementation, the impact of the program on students and student leaders, and changes in teaching or testing due to the workshops.

Format. Different professors and institutions have adapted the workshop format to mesh with their own goals and departmental programs. Two of those interviewed have reduced lecture time by one hour in order to accommodate the workshops. For two others, the workshop substitutes for a recitation or discussion class. One has taken time for the workshops from laboratory time. Four have added the workshops without reducing the time of the existing lecture and laboratory. Of those interviewed, six have two-hour workshops, and three have workshops of one hour or less.

Two of the professors who originally increased student time from six to eight hours per week plan to maintain the workshops, but reduce the total time to the traditional six hours per week. Another is considering increasing the total time by about 30 minutes. Several of those interviewed believe that lecture time can be reduced in order to effect a shift

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from passive to active learning. One professor voiced opposition to this idea, believing that a reduction would impede student learning.

The proposal states, and all those interviewed agreed, that the ideal workshop size is six to eight students with a student leader for each group, but the availability of qualified student leaders as well as project funding have imposed limitations. One professor has workshop groups of about 20 students that break into three smaller groups with students from the class acting as leaders. Another professor uses groups of about 10 that form two smaller groups; the workshop leader rotates between the two groups. Two of the professors reported that they run some of the workshop groups themselves. One uses graduate TAs who oversee the laboratories to lead workshop groups.

About half of the professors reported that they use grades for problem sets or quizzes to ensure attendance and participation. Several said that some students did not attend regularly. One professor felt that mandatory workshops militate against those students who are not team learners, but several others who also had experience with a voluntary format believed that required workshops contributed to better overall organization. Several respondents described current or past problems in scheduling workshops, but most of these either have been solved or are in the process of being rectified. Some professors use a portion of the workshop time for additional instruction, or have workshop groups form during part of the lecture time. One uses the workshop as part of the laboratory time, convinced that the workshop will strengthen the link between the conceptual lecture material and the experiential laboratory work.

All of the professors spend time each week, usually an hour, with the workshop leaders, preparing them for the coming workshops, reviewing materials and chemistry problems, and discussing issues related to instruction and group dynamics. One institution has a separate two-credit course that all workshop leaders must attend. This course covers learning theory and practice, and it also provides a structured support system for the student leaders. As part of the course, student leaders maintain logs recounting their experiences (for more on the logbooks, see the section “Leader Logs”). Several professors are in the process of preparing new learning materials and problem sets for the workshops, often in collaboration with workshop leaders, graduate assistants, and colleagues.

Impact on students. Professors were in general agreement that workshops are beneficial to students. Several said that, as a result of the workshops, students were more familiar

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with the material, that they were reading ahead, and that they came in larger numbers for tutoring. They also noted the growth in students' willingness to question and even challenge what was presented. One respondent saw an increase in analytical skills; another was impressed with the students' enhanced self image. One professor viewed the workshop students as friendlier and less competitive than their counterparts in non-workshop courses. Another thought that an attachment to the group led to increased personal involvement, and that this in turn led to better retention in learning. Several believed that they had seen students take on increased responsibility for their own learning.

All but one felt that the behavior and attitudes mentioned were significant educational achievements. One felt that for very weak students the workshops might be harmful because they reveal shortcomings in a somewhat public forum. One or two others said that more advanced students were sometimes uninterested in the workshop discussions. Another saw positive differences among workshop students in the learning and use of certain vocabulary. He felt this was due to the group format.

Impact on student leaders. The professors interviewed were unanimous in believing that the program has been highly beneficial for the workshop leaders. Here are a few comments they made about the leaders' participation:

- "Their learning is reinforced and they become more verbal about it."
- "At the end they are just magnificent in terms of what they know, and the way they communicate."
- "Makes the concepts of chemistry more concrete in their minds."
- "Got student leaders more engaged in the material, especially when it was in a different context."
- "Adds a dimension to their academic lives that is very positive.

Impact on professors. The professors, in general, had recognized many of the barriers to student learning before adopting Workshop Chemistry. They joined the project because the workshop approach offered a workable mechanism for change that was consistent with their view of teaching and of student needs.

When asked about assessment in general and testing in particular, almost all said that they had made little or no change in these areas as a result of Workshop Chemistry. Most

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felt that they were still rather new to the program and that some incremental changes were likely in the future. On the other hand, it was clear that the individual faculty had designed workshop materials to fit their own courses. Two said that they had begun on occasion to break students into discussion groups for a part of the lecture class. Several said that their own interaction with students had increased as a result of the workshops.

Focus Groups of Students and Workshop Leaders

One such assessment tool has been focus groups, which have been implemented at City College in order to gather the reactions of students and leaders to the General Chemistry workshops. These groups were conducted in the spring of 1995 by the project evaluator. Three focus groups of nine or ten participants were held, two for leaders, and another for students. Questions developed and modified in consultation with the professors were used to promote discussion.

Overview: Lecture and Workshop. Students and leaders enthusiastically endorsed the use of workshops to complement lectures. Many times, focus group members declared that they could not understand material as presented in the lectures. They thought that the professors sometimes assumed knowledge, “started in the middle,” or “took short cuts.” They wished that the professors would “stay on a topic a bit longer.” The reasons for their own reluctance to ask questions included the anxiety associated with speaking in a large group, the fear that the professor and their own peers would think that a question was stupid, a feeling that the professor would simply explain the material again in the same way, an inability to formulate a question, a lack of time, and the difficulty in getting the professor’s attention.

In contrast, the students found that in the workshops anxiety is reduced, leaders are accessible, and peers are supportive. They no longer feel isolated in the learning enterprise. Their incomplete knowledge is no longer felt as a liability, but is actually an asset because it permits them to join in group activities, helping and being helped according to need. Some of the leaders contrasted this approach to other courses in which “students might not say anything for a whole semester.”

Workshop Methods and Dynamics. The leaders and students agreed that one-to-one help with problem solving and with new concepts was a great benefit. The workshop

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leader is viewed as a peer, sometimes a friend. It was said frequently that the leader was able to explain things in a different way." This different way meant several things: supplying background information, breaking the material into smaller chunks and showing connections, and using different vocabulary and examples. Several of the leaders found it rewarding to help students strengthen their math skills.

It seems also that the leaders were successful because learning was individualized with questions possible at each step and because the affective environment was so different from the classroom. The students liked the leaders because they are close in age, "know where you are coming from," and "the way you understand things." They also liked the informality of the workshop setting, and the atmosphere that encouraged them to speak their minds. Both leaders and students believed that, since the leaders have recently completed the course, they were close to the material and could explain it well.

There was agreement in all groups that students started out feeling and acting alone, carrying over their classroom attitudes to the workshops, but within a few weeks, behaviors changed. Workshop leaders asked their students to explain problems. As these students became increasingly confident, they began questioning and helping one another. They found it beneficial that sometimes the same idea would be expressed in different ways by different students. They also noted the way in which learning is deepened through expression: "If you can explain, you understand it."

One workshop leader noted that cooperative activities are common in research and business, so it is important that they and the students learn to work together to solve problems and to build on each other's insights.

Learning and the Workshops. The importance of mistakes came up in the first focus group. One of the leaders said that the workshops gave students "the chance to make a lot of little mistakes." These mistakes, in turn, helped "make connections inside the brain." Students said that fear of making mistakes was constricting, but in the workshops, saying or doing something stupid is okay. Students usually regard their peer leaders as less threatening than their professors, so they feel free to express themselves. When fear was diminished, they were free to try out different ideas, to see where they led, to see what worked.

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Students described how workshop leaders sometimes made mistakes. They, the students, were not afraid to challenge the leaders, and to argue their points. (They said that if the professor made a mistake, they would think he or she was right.) One leader said that, through arguing, “the conversation will stay in their heads longer.” The leaders felt strongly that mistakes meant much less in a workshop than in the lecture: “I’m not a teacher.” “It’s not a big deal.”

The leaders indicated that their own interest in chemistry had grown through their involvement with the workshop program, and several reported changing their majors from biology to biochemistry as a result of their participation. Another said that being a workshop leader helped her develop a more systematic way to study.

Student Questionnaires

Students have frequently been invited to offer written feedback about their experiences in the workshops. We have observed that these comments, which are usually very favorable, often speak to similar issues, despite the differences in our courses, our student profiles, and our campuses. Student comments are available in a separate file (stntques.pdf).

Leader Logs

At the University of Rochester, workshop leaders enroll in a two-credit training course called Issues in Group Leadership, taught by Dean Roth, the director of Learning Assistance Services. One of the requirements of this course is to keep a log throughout the semester. These response journals have proven to be an assessment tool that is both effective and economical in terms of the time required of group leaders and their training course instructor. The format is very simple: leaders are asked to respond each week to the general prompt: “Tell us how your group went this time, and the instructor writes a reply before the next group meeting. As group leaders are selected on the basis of previous demonstration of academic responsibility, they tend to approach their journal writing with a high level of commitment and competence. Sample entries from the leader logs are available in a separate file (leadrlog.pdf).

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III. Future Development and Assessment

We are in the initial stages of the Workshop Chemistry project. While first developed for general chemistry courses, the concepts built into the model are quite general and flexible; thus, they can easily be adapted to other courses, different student groups, and different teaching styles. The positive responses from students, leaders, and faculty demonstrate the broad applicability of the model, so we feel confident about the future development of the project.

Training of Workshop Leaders

In order to be most successful, student leaders need training in group leadership and pedagogical issues. They also need an appropriate support structure as they enter into this new venture. We have had some initial positive experiences with our leader training; we intend to pursue vigorously the development of our training programs.

Connecting Workshop Leaders with Teaching Careers

The workshop leaders have experienced an innovative teaching method. Having had this rewarding and pleasant experience, they form a natural pool of potential science teachers. We are striving to establish a formal connection between participation as a workshop leader and involvement in activities designed to lead to a career in teaching. For example, at City University, workshop leaders are recruited to enroll in a series of courses in science education, which leads to a student teaching experience in a partner high school. The goal is to provide science majors with the opportunity, knowledge, and skills to become teachers of secondary school science in an urban, multicultural school environment. In other contexts, the workshop leader experience has encouraged students to apply for teaching positions in other courses and to think more seriously about graduate school academic careers.

Working with the Budget

We recognize that developing a long-term commitment on our campuses to the Workshop Chemistry model requires careful attention to larger budgetary and program issues. It is important, for example, to pay the workshop leaders; we have found that about $500 per workshop per semester is acceptable in the contexts of our institutions. These stipends

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will usually be new costs for the courses, with the total costs varying with the size on the enrollment. When cost-cutting is the rule of the day, these new costs can be justified only by associated gains in productivity. Our institutions are well-served by courses that provide mechanisms that help students do successful work in traditionally difficult courses. Gains in completion rates, student satisfaction, and student learning are real gains in institutional productivity. The workshop model also provides a mechanism for institutions to identify and develop a cohort of student leaders. Our leaders report that they have grown in confidence, understanding and aspiration as a result of the workshop experiences. These are also real productivity gains for the best of our students.

Departments with well-developed graduate programs present special problems. In particular, it would not be acceptable to eliminate graduate teaching assistants entirely by substituting undergraduate leaders, because this would undercut some of the financial support for the graduate program. On the other hand, it is possible to construct a win-win situation in which a mix of graduate and undergraduate workshop leaders is used, at constant cost, but with substantially reduced section size. Graduate students might also assist in the coordination and training of leaders. The graduate students would continue to receive departmental support, and would learn by participating in the innovative teaching approaches of the workshop model.

Community colleges seldom have access to graduate student support, so it is very important to find ways to finance undergraduate leaders. Work-study grants and funds from existing tutorial budgets are the most likely sources. Grants for workshop leader assistantships, scholarships, or fellowships may be other sources. Since community college students usually work and so do not spend as much time on campus as their senior college counterparts, it is very important to build time and incentives into their programs so they can serve as workshop leaders.

Developing assessment tools

We have only begun to collect data about Workshop Chemistry. Many areas of potential investigation remain. Assessment should influence teaching and learning; its purpose should not be simply to monitor the project, but to be part of the learning experience for all the project participants. We have to learn a great deal more about what actually takes place in the workshops. We know that they involve a lot of discussion; that they are not lectures, recitations, or simply problem solving sessions; that there is some team

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learning, some problem solving, and some tutoring; that some students participate freely while others are more reticent. But we hope to learn a good deal more about the workshop interaction and the strategies employed. Overall, we need to develop further the tools to assess how we meet the various goals of the project.

IV. Conclusion

The results of a wide variety of evaluation tools, including faculty interviews, focus groups, student questionnaires, and leader logs, indicate that the peer-led team learning is a workable model that overcomes many of the barriers to student success. This approach establishes a sense of community in large, introductory science courses. It also allows for the expression of a wide variety of learning styles, and it establishes a very powerful system of peer interaction to draw students into the active study of science. Overcoming these barriers has resulted in significant educational achievements.

Everyone who has been involved in the Workshop Chemistry project has agreed that it has been gratifying to witness the excitement and enthusiasm of students as they become active participants in a collegial network of learners. It also has been rewarding to watch the development of the workshop leaders; each semester we have witnessed the transformation of bright, but nervous undergraduates into leaders, who more confidently see themselves as part of the scientific community. Although our training courses are still being developed and refined, we believe that the essential ideas embodied in these programs merit expansion, not only on behalf of our colleagues in other chemistry departments, but for our counterparts in other science departments as well. We feel certain that they will find, as we have, that this growing cadre of group leaders will become a framework for the kind of interactive, personalized instruction in science towards which many of us are aiming.

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REFERENCES

1. Tobias, S. *They're Not Dumb, They're Different: Stalking the Second Tier*; Research Corporation: Tucson, AZ, 1990.

2. Seymour, E.; Hewitt, N. M. "Talking about Leaving; Factors Contributing to the High Attrition Rates among Science, Mathematics, and Engineering Majors"; final report to the Alfred P. Sloan Foundation on an Ethnographic Inquiry at Seven Institutions; University of Colorado: Boulder, CO, 1994.

3. "The Freshman Year in Science and Engineering: Old Problems, New Perspective for Research Universities"; a report of a conference sponsored by The Alliance for Undergraduate Education: Ann Arbor, MI, 1990.

4. *American Chemical Society*. *Committee on Professional Training Newsletter* **1995**, *Fall (8)* 1.

5. Tinto, V. *Rev. Ed. Research* **1975**, *45*, 89.

6. Manis, J. D.; Thomas, N. G.; Sloat, B. F.; Davis, C. "An Analysis of Factors Affecting Choices of Majors in Science, Mathematics, and Engineering at The University of Michigan"; CEW Research Report #23; The University of Michigan: Ann Arbor, MI, 1989.

7. Treisman, U. Z. *College Math. J.* **1995**, *23*, 362.

8. Gardner, H. *Frames of Mind: The Theory of Multiple Intelligences*; Basic Books: New York, 1985.

9. Belenky, M. F.; Clinchy, B. M.; Goldberger, N. R.; Tarule, J. M. *Women's Ways of Knowing*; Basic Books, 1986.

10. Tobias, S. *Revitalizing Undergraduate Science*; Research Corporation: Tucson, AZ, 1992.

11. Light, R. J. *The Harvard Assessment Seminars: Second Report*; Harvard University: Cambridge, MA, 1992.

12. Woodward, A.; Gosser D.; Weiner, M. *J. Chem. Educ.***1993**. *70*, 651.

13. Cooper, M. M. J. Chem. Educ. 1995. 72, 162.

14. Dougherty, R. C.; Bowen, C. W.; Berger, T.; Rees, W.; Mellon, E. K.; Pullman, E. *J. Chem. Educ.***1995**. *72*, 793.

15. Dinan, F. J.; Frydrychowski, V. A. *J. Chem. Educ.***1995**. *72*, 431.