Chapter One
The Peer-Led Team Learning Workshop Model

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An effective, proven model for teaching undergraduate science is the Peer-Led Team Learning (PLTL) Workshop, first used in teaching chemistry (Gosser and Roth 1998; Gosser and et al. 1996; Woodward, Gosser and Weiner 1993). The PLTL Workshop provides an active learning experience for students, creates a leadership role for undergraduates, and engages faculty in a creative new dimension of teaching.

In weekly two-hour Workshop sessions, students work together on challenging problems and discover that learning science is an intensely human activity, replete with joy and laughter, and struggle and frustration. Simultaneously they learn to take ownership of the material by using the language and ideas of science in focused discussions with their classmates. The model uses peer leaders to facilitate the cooperative work of small groups of six to eight students. These *Workshop leaders* are students who have done well in the course previously and are trained for their leadership roles.

The PLTL model is powerful. For the students, it increases their enthusiasm for the study of science and increases their success in the course. For the Workshop leaders, the experience of working with faculty and guiding others through a difficult course is unforgettable and can have profound effects on the leaders' growth. For the faculty, the model opens new dimensions of teaching, free from the constraints of the lecture. For all, the model creates a new sense of community. The PLTL model is robust and has been successfully employed in a variety of institutions, including community colleges, liberal arts colleges, technical colleges, large state and city universities, and private research universities.

This introductory chapter describes

- the basis of the Workshop model in learning theory, leadership, and team performance;
- the *Critical Components* of successful PLTL Workshops; and
- the impact of PLTL Workshops on students and student leaders.

The other chapters in this *Guidebook* were written by students, faculty, learning specialists, and evaluation experts who have contributed to the development and understanding of the PLTL Workshop model. Each section provides guidance to those who decide to launch student-led Workshops in their classes.

Lecture and the Student Experience

Traditional instruction relies primarily on the lecture: a method of presentation of concepts, models, content, and problem-solving methods by an expert to a group of listeners and note-takers. In addition to providing students an expert view of the subject, the lecturer plays other positive roles, such as communicating a clear set of course expectations, professing enthusiasm and commitment to the subject, and modeling ways of thinking and analyzing. These are important outcomes, and thus the lecture maintains a significant role in the Workshop model.

Despite its traditional standing, the lecture/recitation method has limitations that are related to the lack of student involvement. In a typical lecture setting, the chairs are pointed (often fastened to the floor) in the direction of the lecturer. Even for the most active listeners, communication is primarily one way - from lecturer to student. Recitations are meant to be more interactive, but all too often they devolve into problem-solving lectures. Neither lecture nor recitation is a place where students can balance the receptive modes of listening with active participation in problem solving and scientific discussion and debate.

The Reflective Practitioner

Donald Schon coined the phrase "reflective practitioner" to describe the special kind of problem solving used by professionals to deal with complex problems (Schon, 1983). Such problems require the individual to interact with the problem in a reflective way because the problem cannot be solved by applying ready-made formulas. For the scientist, this means incorporating unexpected results and planning new experiments. For the architect, it means looking at the consequences of a proposed design and redesigning accordingly. For the teacher, it means listening to the students to understand their points of view; it means using flexible structures that respond effectively to the students' differences. Schon observed that many traditional college curricula are out of balance, with an overemphasis on the codification of knowledge and an underemphasis on the actual practices and processes that lead to independence and mastery.

An alternative to the top-down, lecture-only model of teaching is one that builds collaboration and peer leadership into the course structure. Although formal teams are used extensively in the workplace, they are a new concept in higher education. The PLTL Workshop model embodies the spirit of the problem-solving teams that characterize many modern enterprises (Reich 1991; Ainsworth 1999).

> *... symbolic analysts work in teams. Learning to collaborate, communicate abstract concepts, and achieve a consensus are not usually emphasized within formal education, however.*
> *Robert Reich,* The Work of Nations

The Wisdom of Teams

What are the "teams" to which Reich refers? They are reflective practitioners working together to solve complex problems. The *Wisdom of Teams* (Katzenbach and Smith 1993) is an intriguing study of actual teams in a wide variety of settings. Often, the teams were formed to confront daunting performance challenges. Through intense collaborative work, the team members developed the personal and professional resources and understanding that was needed to solve the problems. Whether it was the struggle to change the way railroads do business or to transform a little-known college basketball team into a national competitor, these small teams of about a half dozen participants achieved results that could never have been imagined by the individual members of the team. The essence of these high performance teams, according to Katzenbach and Smith, is "... a small number of people who are committed to a common goal, a common working approach, and to one another's personal growth and success."

Teams and Learning

Cognitive science identifies language as a central feature of learning. The process of expression, debate, discussion, and consensus is an effective way for students to learn the language of science and to construct their own understanding. Learning teams are a natural way to get students to talk to one another. They are particularly useful because students have compelling reasons to work together; they are faced with a difficult course and challenging problems. The diversity of viewpoints works to the advantage of the learning teams. The interchange in the

group is like a distributed intelligence network, providing many opportunities to utilize different learning styles and to offer multiple representations.

During the first years of college, students have the greatest need to connect with others and become part of a community of learners. Although mentoring relationships are recognized to be important ingredients of interest and success in science, they are largely absent in impersonal introductory lecture classes. Workshop teams that are led by successful students build an extensive network of "proximal" mentoring that includes students, student leaders, and faculty. Theory indicates that the most effective learning takes place when assistance is offered by someone above, but near, the level of the learner's development (Vygotsky 1980; Tharp and Gallimore 1988). It is intriguing to note that the Workshop leaders, who are one or two semesters ahead of their group members, are especially well suited to help the students learn. These ideas are discussed in greater detail in Chapter 7.

Workshop teams provide opportunities for students to engage in reflective problem solving, to take risks, to become comfortable with the possibility of making mistakes, to check their understanding with colleagues, and eventually to triumph in mastering the course content. These are the same reasons that teams are so successful in other settings. The team members become resources for one another; the team leader guides and mentors the team members, providing opportunities at every turn. The support provided by the Workshop leader and the Workshop members helps each student reach his or her potential.

An Untapped Resource

College campuses have all the necessary elements to create Workshop teams to help students learn and develop critical thinking skills. Faculty are seeking to create exciting and compelling experiences for their students, students are eager to do well and to participate, and learning specialists know how to help fashion new environments for learning. The PLTL Workshop model makes use of the untapped resource in the college and university - the students themselves. The students in any class are resources for one another, as team members who build understanding through a mutual interaction and commitment, and, given the opportunity and provided with the appropriate structure and guidance, many students are ready, willing, and able to take a leadership role in guiding other students to learn (see Chapter 2).

The Team Leader

The PLTL Workshop shares elements with other curricular efforts involving a collaborative learning environment (Treisman 1992) and with proven pedagogical tools such as pair-problem solving (Whimbey 1982). However, the use of undergraduate students to take the role of team leaders, *Workshop leaders*, is a fundamentally pioneering undertaking (Woodward, Gosser, and Weiner 1993).

Because the team members are a diverse group with strikingly different approaches and skills to solve problems, the team leader has a special responsibility to guide the team to its full potential. According to Katzenbach and Smith "Team leaders act to clarify purpose and goals, build commitment and self-confidence, strengthen the team's collective skills and approach, create opportunity for others .... Team leaders do not believe that they have all the answers - so they do not insist on providing them."

As the potential team grows ... the leader's job changes markedly. His or her formal authority may go unchanged, but when, whether, and how to use it shifts. The key to the leader's evolving role lies in understanding what the team needs and does not need from the leader to help it perform. The team leader is the ultimate utility infielder ... he or she must be there only to deliver as needed. *J. Katzenbach and D. Smith,* The Wisdom of Teams

The Workshop Model of Peer-Led Team Learning

In practice the PLTL model introduces *a unique curricular structure: a weekly peer-led Workshop.* Each Workshop has six to eight student members and a trained leader. The Workshop leader guides the students in collaborative problem solving, model building, and discussion and debate of scientific ideas. Several years of Workshop evaluations (see Chapter 6) have identified six key elements of successful Workshops.

The *Critical Components* of the Peer-Led Team Learning Workshop Model

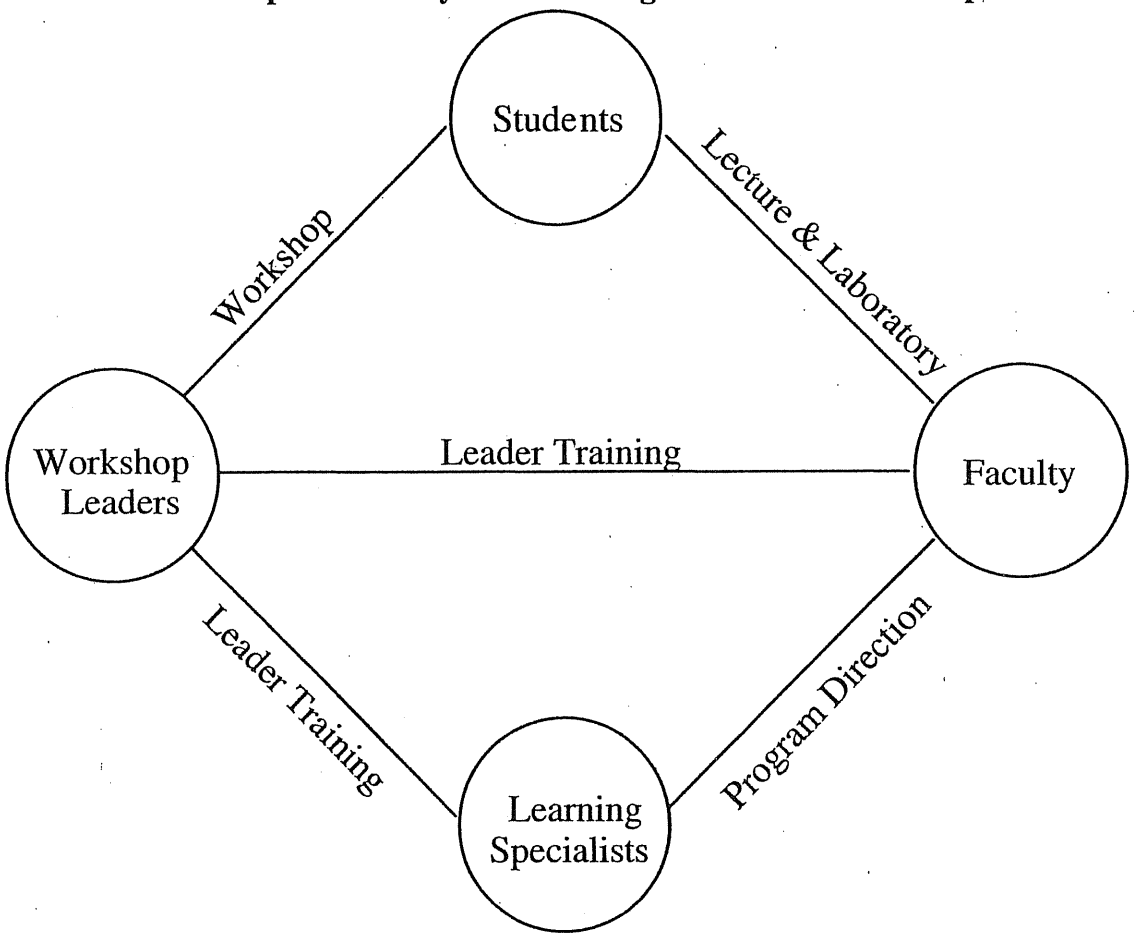
- **The peer-led team learning Workshop sessions are integral to the course and are coordinated with other elements.**
- **The faculty teaching the courses are closely involved with the PLTL Workshops and with the peer leaders.**
- **The peer leaders are students who have successfully completed the course. They are well trained and closely supervised, with attention to knowledge of the Workshop problems, teaching/learning strategies, and leadership skills for small groups.**
- **The Workshop materials are challenging at an appropriate level and, integrated with the other course components, intended to encourage active learning and to work well in collaborative learning groups.**
- **The organizational arrangements, including the size of the group, space, time, noise level, and teaching resources promote learning.**
- **The institution, at the highest levels of administration and pedagogy, and at the departmental levels, encourages innovative teaching and provides sufficient logistical and financial support.**

These six *Critical Components* of successful Workshops are explained in more detail next.

Integral to the course. *Creating the Workshop community.* The nature of the Workshops is defined by the connections among those involved - the students, student leaders, faculty, and learning specialists who operate as a team responsible for the realization of the *Critical Components* (see Figure 1). The PLTL Workshop model not only creates a new role for undergraduate students as leaders but also initiates a collaboration between science faculty and learning specialists. Learning specialists have specific training and expertise in areas closely related to the theory and methods of the PLTL Workshop. There is significant potential for productive cooperation between faculty and learning specialists (who may be located in a learning assistance center or a faculty development center). Although a learning center may be able to provide logistical support for Workshops, the more important function for the learning specialist is to collaborate to create training sessions for Workshop leaders and to support faculty development in learning theory and practice. In turn, the collaboration provides a mechanism for

building close working relationships between learning centers and the curriculum. These connections lead to increased communication and creative solutions for educators and students.

Figure 1. The Workshop Community is the Driving Force of the Workshop Model



The student-led Workshop is an integral part of the course. At the beginning of the term, the students in a lecture class are organized into groups of 6 to 8 students, selected randomly. Each of these groups is assigned a Workshop leader; for example, a class of 100 would require 14 Workshop leaders. The leader is a student who has done well in the course previously and who has good people skills. The group meets on a weekly basis for the entire semester to engage in problem-solving sessions under the guidance of the Workshop leader. The Workshops are scheduled so that the necessary background has been discussed in lecture; the students are expected to have completed some preWorkshop assignments.

Keys to the success of the PLTL model are that the Workshop is built into the course structure and that the weekly Workshop sessions play a major role in the learning process. The Workshop is neither remedial nor optional. It is not a question and answer session. Rather, it is a carefully structured mechanism to help students build their understanding.

Faculty. In the PLTL model, the faculty become actively involved in creating and promoting the Workshop environment. They are responsible for ensuring that the Workshop materials are closely coordinated with course goals and with other course components. In their meetings with the peer leaders, they model ways to manage interpersonal dynamics within a team. They often guide the leaders through the upcoming Workshop, providing models for both content and leadership. They solicit feedback about the Workshops from the students and

Workshop leaders. The success of the Workshop inevitably has an impact on the teaching philosophy of the faculty. After seeing the benefits of an active learning environment, the lecturer often steps back to reexamine the role and the methods of the traditional lecture.

Leaders. *The peer leader is central to the Workshop.* The peer leader has several roles. Each Workshop leader finds a particular style for a particular group; however, it is clear that the role is not that of lecturer or expert. The Workshop leader does not dispense answers. Assuming the role of guide or facilitator is the key to becoming an effective Workshop leader. The Workshop leader is there to guide the students to actively engage with the materials and with one another. This facilitation has several attendant methodologies, which are described in Appendix I. These include organizing round-robin problem solving, creating paired problem-solving groups, encouraging groups to compare results, offering timely assistance when a group is stuck, and providing encouragement and guidance about the course. A good leader knows when to help and when not to. The Workshop leader needs to set a tone for the discussion in which individual points of view are respected, criticism is constructive, and all members have equal opportunities to participate. Workshop leaders are successful students and often become mentors or role models to their groups. However, because they are close in age and only one or two semesters ahead of their fellow students, leaders remain nonauthoritarian.

> *This is the essence of the team leader's job: striking the right balance between guidance and giving up control.* *J. Katzenbach and D. Smith,* The Wisdom of Teams

Although peer-led team learning is a small-group learning method and borrows from the large literature on cooperative learning and team methodologies, it is distinguished by the element of undergraduate peer-leadership. But why is a leader needed? Our view is that the peer leader liberates and empowers students to take responsibility for their own learning. Although the faculty are very much involved, they do not direct supervise the students during the Workshops. The instructor sets the content and materials and then trusts the team (of students and leader) to find its own way to deeper understanding. The highly structured and defined roles of team members described in the literature of cooperative learning are replaced by a responsive, flexible structure that has been found to be powerful in the context of the workplace; that is, a small group (a team) with a leader.

The leader makes the group coherent and effective by

- clarifying purpose and goals;
- ensuring full participation of the group members;
- building commitment and self-confidence;
- strengthening the team members' skills and approaches to problem solving; and
- creating special opportunities for team members.

Learning the peer leader's role. The Workshop leaders need to learn to do their jobs, and the faculty need to be closely involved in teaching the leaders. One part of this process involves preparation for the content of the Workshop. Although the Workshop leaders are expected to have reviewed the problems in the Workshop, it is important that they have the opportunity to discuss these problems with one another and with the faculty. In these meetings, the faculty member becomes guide and mentor to the student leaders. Although the context of the meeting is to discuss the Workshop problems, the faculty and leaders become more comfortable with one another; the leaders often turn to the faculty for advice about courses and career-related topics. In turn, the faculty turn to the leaders for feedback about the students, the course, and the Workshop sessions.

Being a Workshop leader requires more than content knowledge. The facilitator needs to know techniques for dealing with shy, dominant or unprepared students; teaching tools for working in small groups; ways to utilize different learning styles; and when and how much assistance to offer students. An explicit emphasis on leadership training can add immeasurably to the Workshop program. Trained leaders have more guidance, and thus their work is much more effective and rewarding. The training can be offered by the faculty or by the faculty in cooperation with a learning specialist. Journals that leaders keep can provide important feedback to the faculty and learning specialists and invite the leaders to reflect on their Workshop practices. Leaders learn to record and share their experiences with other leaders. The many dimensions of Workshop leader training are examined in Chapter 4 and in Appendix III.

There is a remarkable enthusiasm among students to become Workshop leaders; most find a great deal of satisfaction in the work they do. Indeed, the PLTL model has stimulated a larger commitment from some of the student leaders. They become involved in the project in a broader sense and contribute to the development of Workshop materials, work on Web pages, and participate in local and national meetings where they teach interested faculty by actually leading them through typical Workshops. These *super leaders* make tremendous contributions, injecting their own special brand of idealism and enthusiasm into the Workshop Project.

The care and attention that is given to the leaders is reflected in their relationship with the other members of the Workshop team. The following comments are from students who attended a joint faculty-learning specialist - Workshop leader training seminar at the City College of New York.

Workshop leadership has a whole new meaning. It is something more than tutoring. It is fostering collaboration and helping students work together.

During the meeting, I had the opportunity to put myself in the shoes of a Workshop leader. However, I did so with the people who administer and coordinate the project. This really gave me a chance to feel like part of the driving force of the project. After the discussion on cooperative learning, I have come to realize how important and helpful group studying can be. By listening to other Workshop leaders, I learned about strategies that will be useful in future Workshops.

Materials. Each Workshop session is built around a set of problems and activities designed and structured by the faculty member to focus on the central ideas and to help the students attain the course goals. The PLTL model is quite flexible and can accommodate many different kinds of problems and materials. However, the Workshop environment is unique and invites some creative work and considerable rethinking of traditional problems. The problems must be designed to help the leader actively engage students with the material and with one another. Vygotsky (1980) emphasized that students learn when they are appropriately challenged. With the help of others (teacher, leader, fellow students), the student can reach new levels of accomplishment and understanding. The Workshop materials provide the challenge, and the Workshop team provides the help.

Problems based on the development of scientific ideas and thought allow students to explore some of the eclectic, intuitive reasoning that is often lost in the distilled wisdom of texts. These might include an exploration of the way Mendeleev created the periodic table or how van't Hoff figured out the tetrahedral geometry of carbon. Problems like these also reveal the epistemological bases of our disciplines.

In chemistry, problems that use molecular models are very effective because they tap into the kinesthetic and haptic dimensions of learning. The models are not mere learning tools but

have played a significant role in scientific thought and discovery. In the process of exploring and manipulating the models, small groups of students can obtain an intuitive understanding for the constraints, interactions, and dynamics of systems that are difficult to intuit from equations, visual representations, or "untouchable" computer animations (Rouhi 1999).

Some PLTL Workshop materials have been specifically structured to enhance group interaction. Several examples are described next. More information on these methods and others, using Chemistry as the content area, can be found in Appendix I.

- A successful and widely used tactic is the round robin. The problem to be solved is broken down into a series of questions, and each member of the group is assigned one part. The method works quite well because each student has an equal voice in the discussion and because a successful solution requires that all students listen to one another.
- Concept maps (Novak and Gowin 1984; Herron 1996) that are created by small-group discussion are useful for reviewing topics such as chemical bonding.
- Workshop leaders report that "pair problem solving" (Whimbey, 1982) is a particularly useful pedagogical tool for getting students engaged. They often pair a stronger student with a weaker student, or a shy student with an outgoing student.
- Problems that involve concrete simulations and illustrate the nature of "play" in science can be utilized to provide insight into many areas of biology, physics, chemistry, and mathematics (Eigen and Winkler 1993).
- Finally, organizing the Workshops into teams that compete with each other in a *Jeopardy*-like tournament is an enjoyable and effective format to review factual material for exams (American Chemical Society, 1977).

Integrating leader training, materials and methods. At the beginning of each term, there is one key session at which the faculty meet with the Workshop leaders to prepare for the Workshops. The *Critical Components* of faculty involvement, training of leaders, examination of materials, and delineation of methods integral to the course are brought together. This is an important experience for faculty and peer leaders that ensures that they have a solid grasp of both content and pedagogical approaches. Creating materials that take full advantage of the PLTL approach and training the peer leaders to implement these materials are exciting tasks for the faculty. The instructor often leads a working session, using the materials that the peer leaders will use in the upcoming Workshop. This helps clarify the peer-leaders' understanding and illustrates models for leading the Workshop. The meeting also provides an important run-through to field-test the methods and the materials. The leaders' perspectives often reveal ambiguities in the materials, so they can be modified before they are used. In addition, new ideas for collaborative learning can be explored and tested in advance.

The following general hints are designed to help newcomers design and implement appropriate Workshop materials. More information is provided in Chapter 3. With the guidance of a trained leader, the group can quickly move, without trouble, into many different kinds of materials and modes of collaboration.

- Avoid lengthy explanations or complex instructions. The students have attended lecture, read the text, and worked some problems. The Workshop should take advantage of their prior knowledge and build on it.
- Do not start from scratch. Use your old problem sets and exams and modify their structure, content and purpose to fit the Workshop model.
- Aim for diverse responses to different learning styles by having students explain and compare results.

- Aim for quality, not quantity, in the PLTL Workshop. Doing a few representative problems well and allowing time for reflection and discussion is better than rushing through many examples. The latter will lead to the use of traditional didactic methods.
- Structure the problems and the training of leaders to minimize lecture presentation. Do not introduce new content in the Workshops or the leaders will end up lecturing.
- Make the methodology explicit to the leaders by example in the training sessions. The success of the training session is evidenced by the enthusiasm and participation of the leaders. If you lecture to your leaders, what do you think that they will do in the Workshop?
- Do not make answer keys! As tempting as this may be, it kills the Workshops.

Organizational arrangements. Space and time are the major issues. The PLTL Workshop sessions require a space conducive to small-group discussion and work; a lecture hall will not do. A room with a table, chairs, and a chalkboard is ideal. Workshops must be clearly scheduled in advance and must meet on a regular basis. Campuses beginning PLTL Workshops may have to work on scheduling arrangements, to move through the layers of departmental and college approval. Once the success of the Workshops is apparent, this will be easier.

Support. It is important for the administration to understand that the goals of the PLTL Workshop model coincide with the larger goals of the college and the department. The administration can provide support by recognizing and rewarding innovative and effective teaching. An administration that values PLTL Workshops will provide logistical and financial support as well. This support will ensure the institutionalization of peer-led learning teams. These issues are discussed at greater length in Chapter 5.

Evolutionary Phases of a Workshop Team

While each group has its own individual style and way of doing business, the groups usually go through several phases during the term. Readings from the Workshop leaders' reflective journals tell us how the team members gradually recognize the challenges of learning science, learn the benefits of working together, and build a sense of personal commitment to one another.

Phase 1: Trepidation on stepping into a new role. The leaders often express some anxiety as they start to lead a new group.

> *My first day! At first, the butterflies in my stomach were all I could concentrate on, so I took attendance and said a few words about myself and organic chemistry so that the students would see me as part of the group and not some unapproachable Orgo genius.*

> *I definitely have to say that my first day as a Workshop leader taught me a lot about being an effective leader. There is more preparation than I had anticipated, and more patience than I had thought. How could I get them to see that I was not there to dictate answers but to act as their peer mentor?*

Phase 2: Initial support for students. The first exams often confront students with the challenge of learning chemistry, and leaders express their concern and support for the students.

Since most of my students did not do well on the first exam, they were afraid of the second. I told them what happened when I took general chemistry a year ago. In my group, I got the lowest grade. Encouraged by my Workshop leader, who told me I could be a leader too, I started to study harder. So I did well in the course and now I am trying to help other students as I was helped.

Phase 3: The group starts to come together. The leader, who initially has to take a very visible and prominent role in the discussion, finds that the students gradually become confident in group discussion and problem solving. They also take pleasure in noting the positive results.

I was shocked to see my most shy student taking a very active role.

I saw something remarkable today that made me feel really proud. I was delayed and arrived late for the Workshop. When I got there, the students were not waiting for me, nor had they taken up their bags and left. Instead, I saw a student at the board, leading the group in question number one. When I arrived, I had only to say "carry on." This means that the group has achieved a certain level of independence: they can function as a unit on their own.

My group was not exceptional academically; however, they were superb at group dynamics. At the beginning of the semester, I found it necessary to subdivide the group into smaller cooperative learning sets. I also had to make my presence known in the workings of the group. Some of the men had to be needled to participate, while others had to be literally shut up. By the middle of the semester the group was working well without my direct guidance.

Phase 4: Validation of the team leader's effectiveness. The outcomes and evaluation of the course methods are evidenced by the students' test results.

I learned their test grades today and was flabbergasted by the results. One of my students who chronically does badly on the quizzes got a 91% on the test. Another, who never shows up for Workshop, got a 56%. I guess he doesn't understand the importance of Workshops.

The Peer-Led Team Learning Workshop Project

The Workshop Project is a coalition of faculty, students, and learning specialists committed to the PLTL model of teaching science. The project has been supported by the National Science Foundation since 1991. In 1998-1999, more than 50 faculty and 300 leaders conducted PLTL Workshop courses at more than 30 colleges and universities for 2500 students each semester. The guiding members of the project are committed to developing the peer-led team learning model by offering assistance to others who want to start their own Workshop courses. In 1999 the National Science Foundation awarded the PLTL Workshop Project a National Dissemination Grant to support the spread of the model to other chemistry programs and to other disciplines, such as biology, physics, and mathematics.

This *Guidebook* provides a comprehensive introduction to the Workshop model. The peer-led team-learning model has much to offer: increased student enthusiasm and performance, an exciting new leadership role for students, a new sense of community in science and other departments, and a new dimension in teaching for faculty and learning specialists; however, it is often very difficult to introduce change, even the modest change proposed here. The information provided here is not only a *how-to* guidebook but also provides ammunition needed to convince colleagues and administrators that the PLTL Workshop is a cost-effective solution for increasing student performance.

Future Opportunities

There are several exciting challenges before us. We invite you to join us in the exploration and development of these new ideas and opportunities in peer-led team learning.

- Encourage new faculty, students, and learning specialists to implement Workshop courses and to participate in the Workshop Project activities,
- Expand the PLTL model to include biology, physics, mathematics, and earth and atmospheric sciences,
- Increase connections with teacher preparation programs and with high schools;
- Learn from other science initiatives that promote the use of information technology, real-world questions, discovery learning, and guided inquiry (see World Wide Web pages: Curricular Reform Projects),
- Continue research on the development and evaluation of the PLTL model.

The Peer-Led Team Learning Workshop Project Web Page

The PLTL Workshop Web page is designed to provide up-to-date information on project Workshops and presentations, and available materials, and to encourage the development of an interactive database of Workshop implementations and evaluation.

http://www.sci.ccny.cuny.edu/~chemwksp

WWW Pages: Curricular Reform Projects

Bioquest
http://www.beloit.edu/bquest

ChemLinks
http://chemlinks.beloit.edu

Long Island Consortium for Connected Learning
http://www.licl.org

MADCP, Middle Atlantic Discovery Chemistry Project
http://madcp.fandm.edu

Mazur Physics Education
http://mazur-www.harvard.edu/education/EducationMenu.html

ModularChem Consortium (MC^2)
http://mc2.cchem.berkeley.edu

Molecular Science Initiative
http://www.pslc.ucla.edu/MolSci.html

New Traditions
http://genchem.wisc.edu/newtrad/index.html

Problem-Based Learning
http://www.siumed.edu/pblc/index.html

Process Workshops for General Chemistry
http:\\www.chem.sunysb.edu/hanson-foc/index.html

Project Kaleidoscope (PKAL)
http://www.pkal.org

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Appendix I
Group Methods for Workshops: Specific Practice

Reflective Problem Solving

Pair Problem Solving (Ronald Narode, Portland State University). Although there are many types of cooperative learning group activities, pair problem solving seems to maximize on-task behavior by students and affords the greatest opportunity for learning by *all* members of the group (Malter, Narode, and Davenport 1994). It may also be the easiest grouping to organize and manage. The model for the pair problem-solving method comes from Whimby and Lochhead (1981, 1986). These texts also provide excellent sources of problems for training students in the pair problem-solving technique.

The method of instruction using pair problem solving incorporates two key notions:

- constructivism - the idea that students must construct knowledge for themselves
- metacognition - the idea that the vehicle for construction of knowledge is self-reflection

Research indicates that the problems that students work on to develop conceptual understanding are often insufficient for learning. The various relationships among concepts and ideas, which constitute a conceptual web of understanding, are best developed and discerned by active discussion and debate with others (Von Glaserfeld 1988). Although knowledge is constructed individually, it is corroborated largely through consensus, and consensus building is a social activity.

The method assigns *solver* and *listener* roles to a pair of students. The *solver* is responsible for articulating all ideas as they occur. The *listener* tries to understand the process and the solution. Encouraging students to verbalize their thoughts requires them to examine their ideas. They must evaluate those ideas in light of another person's interpretation of what they are saying. Requests for clarification help students catch their errors or shore up good ideas that were still tentative. By exchanging roles of problem solver and listener, students have the opportunity to learn the related skills of explaining and listening.

In the pair problem-solving classroom, the teacher serves as a coach, moving from one pair to another, listening to their discussions and probing student solutions and conceptions with questions rather than answering questions. A student's answer is not acknowledged as either right or wrong. Instead, the instructor listens to the reasons for the answer and either agrees that the reasons make sense, asks for more elaboration, or asks more questions to help the student think about the problem in a different way. Often, the instructor asks the *listener* to explain the other student's solution and to explain why he or she does or does not agree with it.

Instructions to the solver. The approach requires that one student solve a problem by reading it aloud to the other student (the *listener)* and by verbalizing all thoughts on the problem as they occur. The *solver* does all the writing and all the talking about the problem. Meanwhile, the *listener* must suspend his or her own problem-solving activities and concentrate on understanding the *solver's* solution.

Instructions to the listener. The listener has a difficult task.

- *Listen carefully*: ask the *solver* to repeat statements or to slow down.
- *Encourage vocalization*: ask, "What are you thinking?" and "Can you explain what you are writing?"
- *Ask for clarification*: for example, "What do you mean," and "Can you say more about that?"
- *Check for accuracy*: ask, "Are you sure about that?" Several warnings are offered: do not give hints, do not solve the problem yourself, do not tell the *solver* how to correct an error.

Instructions to the instructor. The instructor can promote metacognitive activity by asking questions that require students to reflect on their thought processes. Four such strategies are to (Confrey 1985)

- ask students to discuss their interpretations of the problem;
- ask the students to describe precisely their methods of solution;
- ask students to defend their answers and their solutions; and
- ask students to retrace their steps to review the process they used to solve the problem.

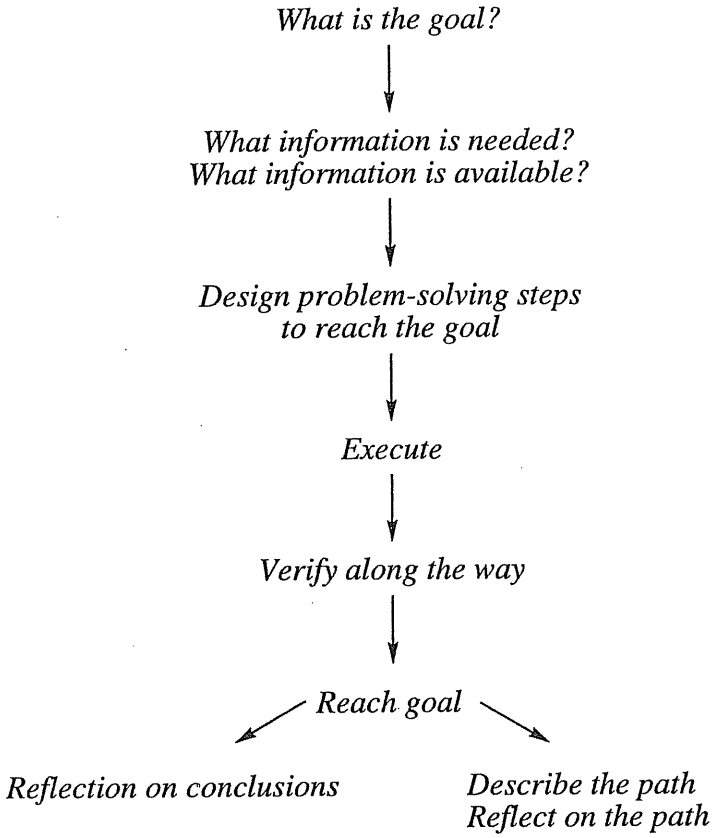
The teacher should direct all questions to the *listener* and not to the *solver.* If the *listener* cannot explain the *solver's* solution, then the *listener* should be directed to ask the *solver* to repeat the solution. The teacher should probe for uncertainties or confusions and indicate agreement as appropriate. When the pair has come to some resolution, they should be encouraged to present their solution to the class. In this manner, the roles of *solver* and *listener* will be reinforced.

Students rarely see experts solve problems, much less hear them solve problems aloud. In addition to listening to students, teachers should model expert problem solving for their students. By describing their thought processes, instructors can demonstrate the process of thinking aloud and reveal the dead ends, mistakes, and corrections that characterize real problem solving.

The pair problem-solving process forces students to articulate their ideas to one another in a manner that causes students to explore their own understanding. In their attempts to explain their solutions and to defend against argument, students develop representations, analogies, limiting cases, multiple hypotheses, straw men, contradictory evidence, and the like. All of these activities require that the conceptual web of understanding grow in subtlety and complexity in the thought processes of the *solver* and the *listener.*

Creating a flowchart (David K. Gosser, City College of New York). Once a problem has been solved it is very instructive to look back on the process that led to the solution. Beginning students are usually not self-conscious about their own mental processes. "I just did it" is a typical description. A retrospective analysis can put form and logic on the process. One way to do this is to ask the students to construct a flowchart of their steps to the solution. The chart makes the thinking process visible. This method would work well to wrap-up the stoichiometry problem (Chapter 3, p. 24) or Observation-Deduction problems (Chapter 3, p. 28). Constructing a flowchart to summarize a pair problem solving exercise would also work well. Subgroups of students could work together to solve problems and then create flowcharts that described their real problem-solving processes. The flowcharts could be exchanged, used and critiqued by other subgroups, or presented to the entire group for discussion.

The following flowchart illustrates an expert view of the process of problem solving. The actual process is more flexible than the flowchart indicates; for instance, it may be in the middle of the design process that one realizes the need for more information.



Interactive Participation

Round-robin (David G. Gosser, City College of New York). The round-robin method for structuring group interaction and discussion has been described in other parts of this Guidebook. The Lewis-dot problem (Chapter 3, p. 00) provides a specific example. In addition to getting everyone involved, round robin focuses the group's attention on specific issues and rations the time among the participants, thereby preventing individuals from dominating the discussion.

Although the stepwise problems that are suitable for a round robin treatment are not the highest order of problem solving, they take on an added dimension in the hands of a skilled Workshop leader. The method is most powerful when the leader encourages reflection and discussion of the nuances of the "well-defined" steps. For example, *which electrons are available for bonding?* (incorrectly defined in some texts) or *why doesn't this particular example follow the octet rule?* It turns out that apparently simple algorithms lead to quite subtle features of problem-solving communication and understanding.

Interview exam (Andrei Lalla, Workshop Leader, City College of New York). Students often need a mechanism for recovering from a misstep (e.g., a disappointing exam). The interview exam is a chance for students to make a good showing and obtain some extra credit. Students are informed that the interview exam is an oral presentation to the Workshop group. The faculty member gives the student the problems for the upcoming Workshop and a

presentation guide (outlined below). The student prepares written answers to the Workshop problems beforehand. These answers are reviewed by the leader at the start of the Workshop. Once the written work is approved, the leader chooses a problem for the student to present to the group. After the oral presentation the leader asks the group for questions and authentication of the answers.

Students are graded on the following criteria:

- Written work: answers, calculations, and explanations as demonstrated in the written work
- Oral presentation: the student is required to follow these three steps:
  i. read the question to the group,
  ii. solve the problem on the blackboard, providing a step-by-step explanation of the solution, and
  iii. answer questions posed by the group and the Workshop leader.

Mendeleev game (Andrei Lalla, Workshop Leader, City College of New York). To help prepare for an exam, students in the Workshop are divided into two subgroups; each subgroup is a "Jeopardy" team. Five or six categories, dealing with major topics covered in lecture, are delineated as five questions and answers. Each question in a category is assigned a point value ranging from 100 to 500. The faculty member works with the Workshop leaders to create the appropriate categories, questions, and answers.

Before the session starts, the Workshop leader tapes the questions face down on the blackboard. The point value is written on the back of the question, facing the students. The questions are organized by categories with appropriate headings. The Workshop leader acts as scorekeeper, and the faculty member is the emcee.

Each subgroup chooses a team captain, and the two flip a coin to see who will choose the first question. *Both* subgroups now work on finding the answer to the same question and writing it down on paper. The first group to arrive at a solution to the question yells ***Mendeleev!***, and the Workshop leader places a check mark on the paper. This ensures that there is no possibility of changing answers during the game. At the same time, the second group should complete their written solution and yell ***Mendeleev!***

The first group to yell ***Mendeleev!*** then presents their answer and if correct, is awarded 200 points plus the point value of the question. However, if the answer is incorrect, 50 points are deducted. The second group answers the question only if the first group's answer was incorrect. If the second group answer correctly, they get 100 points and the point value of the question. This process is continued until all the categories are completed and one team wins outright (American Chemical Society 1997).

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