# Peer-Led Team Learning: Promoting Conceptual Understanding *and* Reasoning Ability

Mark S. Cracolice* and John C. Deming

Department of Chemistry

The University of Montana

Missoula, MT 59812

*mark.cracolice@umontana.edu

## Introduction

In 1961, the National Education Association published an article authored by the Educational Policies Commission titled *The Central Purpose of American Education* (Educational Policies Commission, 1961). In that article, the Commission proposed that "The purpose which runs through and strengthens all other educational purposes--the common thread of education--is the development of the ability to think" (p. 12). The Commission argued that freedom was based on being able to make informed decisions from available evidence. In a free society, people need to have the ability to make decisions about the values they hold, the responsibilities they have, and the consequences of their actions. Since these abilities are not inherited, the Commission went on to argue, "Freedom of the mind is a condition which each individual must develop for himself. In this sense, no man is born free" (p. 3). The Commission also described the need for further research in the areas of knowledge transfer and development of rational thinking, as well as the importance of focusing educational efforts on the development of students' rational powers, or *reasoning ability*. These powers include classifying, deduction, generalizing, and the ability to use proportionalities, probabilities, correlations, and mental models to generate and test multiple hypotheses. Therefore, it can be argued that reasoning ability is of fundamental importance in a free society.

The development of these abilities depends upon the students' genetic potential as well as their interactions with the environment. In one study, researchers found that approximately 75% of college general chemistry students could not consistently apply these reasoning abilities correctly (McKinnon & Renner, 1971). In other words, 75% of students in college general chemistry courses have not reached their full potential in reasoning ability, even after completing their K-12 education. A student will not develop their reasoning abilities if they are not challenged to use them in their academic environment. This gives educators the motivation to search for teaching techniques that promote and enhance the development of these abilities. Cracolice's (1994) study, as well as others, suggest that the traditional use of lecture as the primary method of instruction is not an effective method when enhanced cognitive development is desired (Woods, 1987).

Deming, Ehlert, & Cracolice (2003) found that reasoning ability significantly influences students' capacity to solve conceptual problems in general chemistry. In this study, general chemistry students were divided into three groups based upon their reasoning ability. Their success rates on paired algorithmic (problems that could be solved using a memorized set of procedures) and conceptual problems were then analyzed. Students in the high reasoning ability group were significantly more successful on the conceptual problems than the low reasoning ability group. In addition, there was no significant difference in success rates between the low and high reasoning ability groups on algorithmic problems. These results suggest that conceptual understanding is intimately linked to reasoning ability. Therefore, students who haven't been challenged to develop these skills will falter in courses requiring conceptual understanding.

Even many beginning *graduate* students in chemistry have a poor understanding of chemical concepts (Bodner, 1991). For example, entering graduate students at Purdue University were given the problem, "Assume that a beaker of water on a hot plate has been boiling for an hour. Within the liquid, bubbles can be seen rising to the surface. What are the bubbles made of?" (p. 385). Nearly 20% stated that the bubbles contained air or oxygen, and 5% stated that they contained a mixture of hydrogen and oxygen gas (the correct answer being steam or water vapor). The students also had difficulty with the question, "What happens to the weight of an iron bar when it rusts? Does it increase, decrease, or remain the same?" (p. 386). Nearly 10% argued that there would be a decrease in weight, even though they did not account for this loss as rust falling off the bar. Some students cited a change in density argument to support their conclusion, while others described a situation in which the mass lost would be converted into energy. An additional 6% argued that the weight of the bar would not change. Some students cited a conservation of mass argument to support this conclusion (the correct answer being that the mass would increase due to the mass of oxygen combining with the iron to form rust). These results suggest that instructors should explicitly focus on conceptual understanding in all aspects of chemistry.

Choosing appropriate teaching methods is the first step. For example, in a study of 6542 physics students in high schools, colleges, and universities, researchers found instruction that included interactive engagement methods (IE) was superior to traditional lecture methods (T) (Hake, 1998). In fact, students in the IE groups showed conceptual gains that were 1.8 standard deviations above the T groups. Although Hake briefly described the relative differences between IE and T, he fell short of describing the critical aspects of the interaction that are important for conceptual development. However, altering the current lecture-laboratory-discussion format to become more interactive will provide students the opportunity to attain conceptual understanding.

## Peer-Led Team Learning

Traditional recitation or discussion sections provide little interactive engagement. In most cases, these sections follow a model of instruction where a teaching assistant (TA) completes examples on the board for students. Students have the opportunity to ask the TA questions, but the model discourages any extended interaction. In this model, students are largely passive. An alternative to this model is Peer-Led Team Learning (PLTL) (Gosser et al., 2001). In PLTL, these recitation or discussion sections are replaced by two-hour workshops in which groups of six to eight students are guided by an undergraduate student, called a *peer leader*, who has successfully completed the course. These groups work together to complete assigned material with the peer leader acting as the learning facilitator. Since these assignments focus on conceptual understanding and working beyond "the right answer," the leader's role is to facilitate the interaction of ideas. By doing so, the relative merits of alternative points of view can be argued, and students can begin to choose the best of these from the available evidence. In addition, students who have not yet grasped the concept are able to hear the thinking patterns of the student(s) who have grasped the concept and are able to ask questions at any point that is unclear. The PLTL sessions provide an environment where students can build both conceptual understanding and improve their reasoning abilities.

### *Peer Leader Selection and Training*

Leader selection is the most critical aspect of a successful PLTL program. Either choosing students who have successfully completed the course with an A or a B helps insure they have the content knowledge necessary to facilitate the interaction of ideas. However, if leaders are not able to work well with others, or do not have the patience to allow students to work through their specific difficulties without telling them the correct answer, they will not make good leaders. The single greatest predictor of future leaders' success is found while they are enrolled as students in the course. If they ask "Why?" instead of just searching for the correct answer, they will most likely make good leaders. Therefore, the first step in the leader selection process is to ask the current peer leaders to identify students in their groups that consistently ask how things work and why things work. It would also be beneficial to ask these leaders to identify the students in their groups that are only concerned with generating the correct answer. Those students will not make good leaders. Once good potential leaders are identified, they must be encouraged to apply. Their leaders may also begin to "groom" them to be leaders in future semesters.

After leaders are chosen, they must be trained. A resource for leader training is *Peer-Led Team Learning: A Handbook for Team Leaders* (Roth, Goldstein, & Marcus, 2001). Training should also address content knowledge, pedagogical knowledge, pedagogical content knowledge, and leadership roles. Leader content knowledge is most important. When leaders are comfortable with their own understanding of the concepts, they are more likely to allow students to ask questions and work "beyond the right answer." In addition, professors become more confident the PLTL groups are promoting the appropriate conceptual understanding when they are comfortable with the leaders' understanding.

Pedagogical knowledge is also important. After all, these leaders have no formal teacher training. In fact, this may be their first experience in this type of role. Therefore, it is important to address group dynamics and methods of encouraging interaction. These might include aspects of cooperative learning, how to deal with problems that arise in groups, etc. In addition, leaders must also learn pedagogical content knowledge. Quite simply, pedagogical content knowledge is the knowledge of specific teaching strategies and methods that affect student understanding in a particular content area. This knowledge usually develops through experience teaching the topics. For example, an experienced professor may have developed a specific teaching strategy for a topic after finding that more students benefit from that method than his or her traditional method. The professor might say to a less-experienced colleague, "Try this. I've found students really seems to like this method for that unit." Since leaders haven't had the opportunity to develop this knowledge initially, it is important to provide insight here. One method of doing so could be to have experienced leaders describe what strategies were successful for them on a particular unit.

Leader training must occur throughout the semester. One successful training model begins with two days of leader training prior to the semester, followed by one-hour weekly meetings throughout the semester. In the two-day training session, new leaders are given the opportunity to work in PLTL groups with experienced leaders modeling appropriate leader behavior. Through this type of role-playing, new leaders are given the opportunity to ask questions and discuss foreseeable problems. By doing so, they learn some of the intricacies of the leadership role they will fulfill.

### *Materials*

PLTL groups must have specific materials designed for group work. In addition, the materials should focus student attention to specific concepts that have proven difficult to past students. Although some of the questions are designed to provide students the opportunity to practice using their newly acquired concepts, most of the questions focus on developing strong conceptual understanding. Leaders are instructed to dwell on these questions and to ensure all members of the groups are comfortable with the concepts before continuing. Examples of these materials are available for chemistry, biology, mathematics, and physics at www.pltl.org.

As Musheno and Lawson (1999) have shown, a key element in the development of quality materials is to utilize a data-to-concepts approach. Ideally, the body of a problem will consist of data, preferably empirical data, as well as the experimental setup used to generate the data. Students will be challenged to "make sense of the data," and questions will focus student attention on hypothesis generation and testing. After leading students from data to concept, follow-up questions should ask students to apply the newly-learned concept in new settings. Additionally, questions can be used to allow students to practice their newly-learned problem-solving skills. It is important to keep in mind that PLTL materials will be used in a group setting with the guidance of a peer leader, and thus questions that can be solved by an individual working alone are not appropriate.

*Evaluation and Research*

The evidence documenting the effectiveness of PLTL is compelling. For example, Tien, Roth, and Kampmeier (2002) compared students in otherwise equivalent PLTL and non-PLTL organic chemistry courses. Three years of non-PLTL course offerings ($n$ = 942) were compared with four years of a PLTL curriculum ($n$ = 1215) with the same instructor using the same textbook and exams of equivalent difficulty. All students, no matter their gender or ethnicity, benefited from the PLTL approach. Retention improved, exam performance improved, and students had better attitudes toward the course after the PLTL curriculum was implemented.

In an analysis of PLTL effectiveness, institutions from community colleges to research one universities were assessed to determine the percentage of PLTL and non-PLTL students achieving a passing grade of A, B, or C (Gafney, no date, at www.pltl.org; research and evaluation section; student performance subsection; comparing student performance page). Ten schools compared PLTL groups to historical data of non-PLTL courses. In these analyses, 58.2% of students in the non-PLTL groups earned passing grades, while 72.4% of the students in the PLTL groups earned these grades. Eight schools compared the grades of students self-selecting into PLTL or non-PLTL groups. In these analyses, 65.5% of the non-PLTL student earned passing grades, while 81.3% of the PLTL student earned passing grades. In one study at the University of Pittsburg, students were randomly assigned to either non-PLTL or PLTL groups. In this study, 83% of non-PLTL students earned passing grades, while 90% of PLTL students earned passing grades. The preponderance of the evidence is clear--PLTL works.

PLTL is only effective when six criteria are met (Gafney, 2000). Gafney identified these as the six "critical components," but it is important to note that at least one of the six was not met in every instance when PLTL implementation failed. The first is the *integration of PLTL assignments with the total course*. Students must see the value of PLTL groups. They must believe the groups provide insight for concepts they are learning in lecture and/or the laboratory, and make the connection between what the are learning (and being tested on) and the PLTL group work. The second is the *involvement of the PLTL instructor.* The instructor must integrate the lecture, laboratory, and PLTL portions of the course. In addition, the instructor should show the students that PLTL assignments are important. This can occur by including PLTL questions on exams and by pointing out how the PLTL assignments relate to the current lecture topics. By doing so, the instructor gives the PLTL groups credibility within the course framework.

The third is *leader training.* Leaders must be able to handle groups of diverse students, facilitate the interaction of ideas rather then acting as a lecturer, have an initial training program before they begin as peer leaders, and have the necessary content and pedagogy knowledge. The fourth is *materials.* The materials must be challenging and designed for group work, though not so challenging as to discourage students. The materials must also reflect the types of questions the professor determines appropriate for exams.

The fifth is *organizational arrangements.* PLTL groups should meet in a two-hour block once per week. Groups should include six to eight students and one leader. Attendance must be mandatory, and the space must be conducive to small-group interactions (moveable chairs, a whiteboard, etc.). The sixth is *institutionalization.* PLTL requires resources, and these resources must be available after any initial grants expire. Initially, this may mean implementing PLTL in new courses within the same department. From there, other departments can be included and administrators can view PLTL's success. These critical components must be continually monitored to insure the long-term success of any PLTL program.

**Building a National Network**

Most recently, the primary focus of the PLTL project is to build a national network of PLTL practitioners to insure ongoing sustainability of the reform of introductory science course curricula. In addition to the PLTL project center at the City College of New York, regional project resource centers have been established, each of which specializes in providing project leadership in a specific area.

There are a number of areas in which efforts are being concentrated to establish a national network. An ongoing effort is support of the Workshop Project Associate program where new PLTL implementations are awarded modest financial start-up support, as well as mentoring support from experienced PLTL practitioners. Awards are being made in chemistry, which is the original discipline for the reform effort, and now the project is extending into biology, physics, and mathematics, where the PLTL model also has been shown to be effective. All new implementations are part of a large-scale control-group quantitative study of PLTL versus non-PLTL students' content knowledge and attitudes about learning gains.

The national network effort also includes work in utilizing the PLTL model to recruit and train teachers, improve the quality of leader training, and increase the involvement of leaders in the dissemination effort. Similarly, more faculty are becoming involved in the dissemination effort, and new leadership is emerging. As the project grows, more ideas are coming forward to break down implementation barriers and promote collaboration among faculty, both within an institution and between institutions.

**A Blended Curriculum**

At The University of Montana, we use a blended approach in our general chemistry curriculum that incorporates some elements of Peer-Led Team Learning with some from the Process Oriented Guided Inquiry Learning project (POGIL) (Farrell, Moog, & Spencer, 1999; Hanson & Wolfskill, 2000; Spencer, 1999). There is also an overarching theme of incorporating guided inquiry throughout the curriculum, in both lecture and laboratory (Monteyne & Cracolice, 2004; Pavelich & Abraham, 1979). Our approach is similar to the Peer-Led Guided Inquiry curriculum at the University of South Florida (Lewis & Lewis, 2005), but we use peer leaders in every "lecture" session, as well as in the weekly two-hour PLTL session.

In the three 50-minute periods traditionally assigned to lecture each week, we seat students in a large lecture hall in their six-to-eight-student PLTL groups with their peer leader. We use a lecture hall large enough to allow single-row buffer zones between groups, and students sit in the same location throughout the term. In each period, the instructor delivers a series of two or three mini-lectures, which usually are formatted to provide sufficient information from which students can solve problems or answer conceptual questions, but we avoid working examples or drawing conclusions. After each mini-lecture, which typically lasts five to ten minutes, students work in their PLTL groups to answer questions from a workbook prepared for this purpose. Peer leaders are trained in both content related to the questions and the appropriate pedagogical approach to assisting students in finding solutions. This approach allows students to actively construct knowledge about chemical concepts and problem solving, and it gives them an opportunity to interact and ask questions of one another and their peer leader.

## Conclusions

Peer-Led Team Learning challenges students to become active participants in their learning process. The teams develop comfortable environments in which students are able to ask questions and work together to improve each other's understanding. Since leaders were successful students in the course previously, they act as positive role models for students in their groups. They are able to model the thinking skills and work ethic necessary to succeed. The leaders also focus students' attention to the important details found in PLTL workshop problems, which helps to raise the level of student understanding.

A combination of the PLTL approach with other curriculum models has great potential for dramatically improving the quality of student learning. By incorporating the POGIL approach in lecture and the PLTL groups in place of recitation/discussion sections, or some combination thereof, instructors will have implemented two very successful and necessary teaching strategies and students will have the best opportunity for success.

---

## References


Bodner, G. M. (1991). I have found you and argument: The conceptual knowledge of beginning chemistry graduate students. *Journal of Chemical Education*, *68*(5), 385-388.

Cracolice, M. S. (1994). *An investigation of computer-assisted instruction and semi-programmed instruction as a replacement for traditional recitation/discussion in general chemistry and their relationships to student cognitive strategies.* Unpublished doctoral dissertation, University of Oklahoma, Norman.

Deming, J. C., Ehlert, B. E., & Cracolice, M. S. (2003, September). *Algorithmic and conceptual understanding differences in general chemistry: A link to reasoning ability*. Paper presented at the American Chemical Society National Meeting, New York, NY.

Educational Policies Commission. (1961). *The central purpose of American education*. National Education Association.

Farrell, J. J., Moog, R. S., & Spencer, J. N. (1999). A guided inquiry general chemistry course. *Journal of Chemical Education*, *76*(4), 570-574.

Gafney, L. (2000). Evaluation strategies. *The Workshop Project Newsletter--Progressions: Peer-Led Team Learning*, *1*(2), 5-7.

Gosser, D. K., Cracolice, M. S., Kampmeier, J. A., Roth, V., Strozak, V. S., & Varma-Nelson, P. (Eds.) (2001). *Peer-led team learning: A Guidebook.* Upper Saddle River, NJ: Prentice Hall.

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics, 66*(1), 64-74.

Monteyne, K., & Cracolice, M. S. (2004). What's wrong with cookbooks? A reply to Ault. *Journal of Chemical Education*, *81*(11), 1559-1560.

Pavelich, M. J., & Abraham, M. R. (1979). An inquiry format laboratory program for general chemistry. *Journal of Chemical Education, 56*(2), 100-103.

Hanson, D., & Wolfskill, T. (2000). Process workshops--a new model for instruction. *Journal of Chemical Education, 77*(1), 120-130.

Lewis, S. E., & Lewis, J. E. (2005). Departing from lectures: An evaluation of a peer-led guided inquiry alternative. *Journal of Chemical Education, 82*(1), 135-139.

Musheno, B. V., & Lawson, A. E. (1999). Effects of learning cycle and traditional text on comprehension of science concepts by students at different reasoning levels. *Journal of Research in Science Teaching, 36*(1), 23-37.

McKinnon, J. W., & Renner, J. W. (1971). Are colleges concerned with intellectual development? *American Journal of Physics*, *39*(9), 1047-1052.

Roth, V., Goldstein, E., & Marcus, G. (2001). *Peer-Led Team Learning: A Handbook for Team Leaders.* Upper Saddle River, NJ: Prentice Hall.

Spencer, J. N. (1999). New directions in teaching chemistry. *Journal of Chemical Education*, *76*(4), 566-569.

Tien, L. T., Roth, V., & Kampmeier, J. A. (2002). Implementation of a peer-led team learning instructional approach in an undergraduate organic chemistry course. *Journal of Research in Science Teaching, 39*(7), 606-632.

Woods, D. R. (1987). How might I teach problem solving? In J. E. Stice (Ed.), *Developing critical thinking and problem-solving abilities, New directions for teaching and learning, n. 30.* San Francisco: Jossey-Bass.

---



Published online: December 20, 2004 for the Winter 2005 CONFCHEM Online Conference: *Trends and New Ideas in Chemical Education*

---