Varma-Nelson, P.; Coppola, B. P. "Team Learning." In, Pienta, N.; Cooper, M. M.; Greenbowe, T.; "Chemist's Guide to Effective Teaching" Saddle River, NJ: Pearson, 2005; 155-169.

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Team Learning

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Abstract

Team Learning is a second-generation pedagogy; that is, it results from a combination of robust and well-established theories and methods for instructional design. Team Learning is presented here as a consequence of a four-part framework, one which combines group (collaborative and cooperative) learning, reciprocal teaching, Vygotsky's educational theory, and studio instruction. Two models of team learning in chemistry are presented: Peer-Led Team Learning (PLTL), a successful model that has been replicated in many venues and in other disciplines; and Structured Study Groups (SSG), which provide a student-led Honors option for students in a large, introductory chemistry program.

Biographies

Dr. Pratibha Varma-Nelson is Professor of Chemistry and Chair of the Department of Chemistry, Earth Science and Physics at Northeastern Illinois University, Chicago. She received her B.Sc. in Chemistry with first class from the University of Pune, India, in 1970 and a Ph.D. in 1978 from the University of Illinois in Chicago in Organic Chemistry. The title of her thesis was "Protein Ancestors: Heteropolypeptides from Hydrogen Cyanide and Water". She completed a Post Doctoral fellowship in Enzymology at the Stritch School of Medicine, Loyola University, Maywood, Illinois before joining the faculty of Saint Xavier University, Chicago in 1979. At SXU she taught courses in Organic Chemistry and Biochemistry. At NEIU she teaches a Capstone Seminar to chemistry majors and Chemistry of Biological Compounds.

Since 1995 her professional activities have revolved around the development, implementation and dissemination of the Peer-Led Team Learning (PLTL) model of teaching. She was an active partner of the Workshop Chemistry Project, one of the five NSF supported systemic reform projects in Chemistry and is currently a co-PI of two NSF supported National Dissemination Grants: "Peer-Led Team Learning: Building the National Network" and "Multi Initiative Dissemination." In addition, she has co-authored several publications and manuals about the PLTL model. Dr. Varma-Nelson is director of the Workshop Project Associate (WPA) Program which provides small grants to facilitate implementation of PLTL and director of the Chautauqua course on PLTL offered annually.

Dr. Brian P. Coppola is *Arthur F. Thurnau* Professor of Chemistry at the University of Michigan, Associate Chair for Curriculum and Faculty Affairs, and a Faculty Associate at the University of Michigan Center for Research on Learning and Teaching. He received his B.S. degree in 1978 from the University of New Hampshire and his Ph.D. in Organic Chemistry from the University of Wisconsin-Madison in 1984, having joined the faculty at the University of Wisconsin-Whitewater in 1982. Moving to Ann Arbor in 1986, Dr. Coppola joined an active group of faculty in the design and implementation of a revised undergraduate chemistry curriculum. His recent publications range from mechanistic organic chemistry research in 1,3-dipolar cycloaddition reactions to educational philosophy, practice and assessment.

In 1998, Dr. Coppola was selected as part of the first group of Carnegie Scholars affiliated with The Carnegie Foundation for the Advancement of Teaching's CASTL program (Carnegie Academy on the Scholarship of Teaching and Learning). He also directs the CSIE program (Chemical Sciences at the Interface of Education), which broadens the scholarly development for all students (undergraduate to post-doctoral) who are interested in academic careers. These students have the opportunity to collaborate on teaching projects with the faculty in the same way that they pursue research projects. The centerpiece of the program is built on the familiar structure of a graduate training grant that provides a novel opportunity for the department's PhD students who wish to add this work to their theses.

Introduction

Knowledge is constructed in diverse ways, following strategies and traditions evolved by the disciplines over time. One way knowledge can be constructed is by individuals working in relative isolation and intense contemplation. This method is probably more familiar to our colleagues outside of the science, technology, engineering, and mathematics (STEM) disciplines than it is to us. Faculty in the STEM disciplines have devised an alternative method of knowledge construction as a response to the increasingly sophisticated demands of modern research. They have refined a system that distributes the responsibility for getting work done over an intergenerational team, namely, the research group (Coppola, 1996; NSF). The faculty advisor is also the research director, and orchestrates the activities of the research group. The roles of research director and advisor are critically intertwined, because this person oversees (manages) the overall direction of the team, while simultaneously balancing the challenges and skill requirements of tasks and matching them with team members in order to fulfill the dual goals of productivity and education. Hoffmann (2003) believes the learning opportunities provided by research groups, as we know them, are the primary reasons why graduate students in the U.S. hopscotch in creative ability over their better-trained European and Asian counterparts during graduate school. The scientific research group is an excellent model for an effective team. The structure of these teams is quite sophisticated because the team (a collection of roles and a process) remains in place, while novices and other new members flow in as trained experts depart. When the Ph.D. is awarded, an individual has stepped through the multiple roles within the team during the educational process, until (based on primarily self-generated results) that person is an expert (an authentic leader) on a narrow body of work.

Regardless of the level, teams work: they educate well and they educate efficiently by structuring and supporting the time a person spends on a task. In this chapter, we argue that progress in understanding designs for teaching and learning is following a parallel path to research, and in response to the same pressure, that is, increased sophistication and the need to do better with more demands within the constraints of finite time and limited resources. Over a relatively short time, instructional design for classroom learning –another version of orchestrating the construction of knowledge – has systematically shifted towards recognizing the value of formally distributing responsibility for teaching and learning by integrating group strategies as a part of effective instructional practices.

Team Learning (or TBL: "Team-Based Learning") has a rich history derived from extensive work in the pre-college arena. Larry K. Michaelsen is generally credited with the generative production and application of these ideas in higher educational settings (Michaelsen, 2004). Team learning positively impacts student learning because it draws from and combines four well-established areas of educational design and research,.We believe provides this a useful theoretical framework for thinking about Team Learning that has been historically absent from the practical recommendations provided by Michaelsen and others (Coppola, 2004). These recommendations are: (1) group (collaborative and cooperative) learning, (2) reciprocal teaching, (3) Vygotsky's educational theory, and (4) studio instruction. Finally, we also agree with those critics who remind us that pedagogies should be intimately aligned with instructional goals rather than treated as universal truths (or 'magic bullets') that represent exclusive solutions

(Coll and Taylor, 2001). In other words, group learning strategies should complement and strengthen other instructional strategies, including the lecture, and all strategies should be exploited for the educational gains that can be best realized through them.

Without a doubt, one of the drivers in undergraduate science education reform has been the inverse relationship between domestic students choosing scientific and technical career pathways as the projected needs of a more scientifically literate and technically proficient workforce are increasing. Not only are graduation rates for students in STEM fields far below national averages for other disciplines, but this is an especially acute problem for underrepresented minorities. One proposition is, that without effective intervention and support, many students decide not to continue in STEM majors or careers. A study by Astin and Astin (1993) reported that 40% of first-year college students majoring in STEM fields switched out before their senior year. Another study by Astin (1993) outlined several factors that positively affect the quality of intellectual development during college years. The ones that are most relevant to the present discussion are: 1) student faculty interaction outside the classroom 2) involvement with student peer groups 3) involvement on campus through various forms of community-building activities and 4) the amount of time that students devote to studying, i.e.,"time on task," including the quality of time spent based on the design of the tasks and how well mechanisms of support (scaffolds) mediate difficulties as they arise. Of these factors Astin (1993) identified "the student's peer group as the most potent source of influence on growth and development during the undergraduate years."

These studies point to a need for using pedagogies that tap into the benefits of collaborative learning techniques. And as argued above, scientists should be able to adapt easily to this way of thinking because doing science relies so strongly on these same methods – although it requires a significant shift in thinking, namely, that the teaching that one orchestrates as a research director is metaphorically related to the teaching one orchestrates in classroom settings (Coppola & Pearson, 1998). In addition as noted by Howard Hills, we have reached a stage where, although "technology will provide more and more learning support," interacting with technologies also reduces the benefits from face-to-face social interaction in building knowledge. Thus, "this collaborative team-learning approach retains the human contact we all need" (Hills, 2001). In this chapter, we review the attributes of team learning as a form of group learning, summarize the characteristics of an effective team leader and suggest some specific pedagogical benefits from organizing team activities as a part of instructional design. We will then provide some brief design features based on our experiences in implementing team learning activities in two specific programs. In both cases, we are defining teams as groups of students in undergraduate courses who are led by another undergraduate student who not only has prior experience in the course, but who has also been identified for and trained in the requisite leadership skills to transform a group into a high performing team.

The nature of teams and team learning

What is the difference between a group and a team? Our colleagues in Business and Business Administration have spent a great deal of time defining these attributes (e.g., Torres & Spiegel, 1991), while those in education have promoted teams as a way to inform the design of learning environments for children (e.g., Atkinson, 2001, Michaelsen, et al., 2002), in translating these ideas for higher education, writes about the transformation of a group to a team in order to produce effective learning: "The key to successful use of team-based learning is knowing how to transform groups into teams which then are capable of producing powerful learning."

A group is a gathering of people who can end up with a variety of organizational characteristics; one of these organizational sets is a team. Katzenbach and Smith define "team" as a small number of people with complementary skills who are committed to a common purpose, a set of performance goals, and an approach for which they hold themselves mutually accountable (1993). They also stated the importance of ground rules, which then become a part of the culture of the team. Their taxonomy of characteristic differences between teams and groups is a useful framework for thinking about the changes that take place during the transformation of a group to a team. The following characterization of teams and groups represents extremes on a continuum.

Hills (2001) observes four stages in the development or formation of teams from groups. These include: excitement, grousing, confusion and performance. The final stage (performance) is the desirable outcome and shortening the time it takes to work through the first three stages is key to the success of Team Learning. The single most important determinant for making progress as a team is the presence of a leader and preparation and training of the leader. A leader maybe an undergraduate student who has previously taken the course, a graduate student or a faculty member. Good leaders can get teams as quickly as possible to the performance stage, where they are effective and efficient without being dependent on the leader.

In describing the five dysfunctions of a team, Lencioni (2002) simultaneously identifies the important organizational goals for building a team from a group. These are: (1) developing mutual trust, (2) creating mechanisms to resolve conflicts, (3) becoming committed to each other in accomplishing tasks, (4) accepting accountability, and (5) attention to quality results.

Characteristics of Teams		Characteristics of Groups
share leadership roles as they see fit		have a strong & clearly focused leader
take mutual, collective accountability		take individual accountability
create specific team objectives that they deliver themselves		objectives are imposed, mandated, granted and/or the same as the broader organizational mission
deliver collective products/outcomes		deliver individual products/outcomes
encourage open-ended discussion and active problem solving meetings		runs efficient meetings
measure performance directly by assessing collective products/outcomes		measure effectiveness indirectly by their influence on others
discuss, decide, and do real work together		discuss, decide and delegate
have open and honest dialogue		have polite discussions
have fun working together and laugh a lot		just work
can't wait to be together		meet because they have to

Learning Outcomes

Individuals depend on (and learn with) one another in multiple situations and settings, including but not limited to those we design for them. In order to emphasize this idea, Bruffee (1995) advocates a phrase attributed to John Dewey as a hallmark educational goal: learning to live "an associated life." As Bruffee describes it, the unique strength of formal education in the United States has been a philosophical basis of "associated learning" since at least the time of Benjamin Franklin. Team learning prepares students to work effectively with people, including those who are different from themselves, by generally building reliance on, and trust and respect for the perspectives and work of others. Including a strong focus on process as well as product ensures that even good students benefit from learning and appreciating diverse approaches. In particular, explanatory and sense-making skills derived from discussion, critique, and other aspects of reflective practice, such as effective revision and editing of others' work and ideas (Schön, 1983). The simplest proposition is that students have the opportunity to express what they know by participating in a team, and in doing so, learning gains should be reflected in traditional measures, such as test scores.

Some models of team learning rely on students who have successfully completed the course to serve as peer leaders while in others faculty themselves may choose to serve as the facilitators of teams. The advantage of using peer leaders is that they - carry what one of our leaders once called "the authority of recent experience" with the university in addition to the course (Coppola, Daniels & Pontrello, 2001).

A significant outcome from peer-led instruction is the effect on the peer leader. The effective habits of good teachers should emerge and be encouraged by students who take on these roles. In addition to numerous anecdotal reports of increased comfort with the subject matter and confidence with addressing ideas in public settings, recent research findings (Gafney and Varma-Nelson, 2001, Tenney and Houck, 2004) point to the following gains when students take on the role as peer leaders:

- Increased content knowledge and better success in higher level science courses.
- Increased confidence to pursue science-related careers.
- An appreciation for different learning styles.
- Improved "people skills" and collegial relationship with the course instructor.

If peer leaders lead the teams they must be provided with proper training and support so that they are effective facilitators. If team learning is used in introductory classes, especially in a large institutional setting or at an urban commuter institution where one's academic life might seem more easily 'dissociated' rather than 'associated,' student leaders can serve as role models as well as facilitate the transition of the new students to college life an outcome that lasts long after the details of the course content have been diluted by other courses as the years go by.

Team learning requires students to negotiate meaning and understanding in debate and discussion with peers. This is the essential mechanism by which scientists construct knowledge and understanding; it promotes the kind of learning that is good for their future. In industry or in an academic environment, scientists rarely work alone, but they do have individual responsibilities within the context of a larger task. In graduate school, they participate in the various functions of a research group, many of which rely on communicating about and building on each other's work.

How and why do teams impact learning? A theoretical framework

There is nothing in the Team-Based Learning literature that points to a theoretical framework for how and why teams have a positive impact on student learning. Here we propose that four previously defined contexts interact and inform Team Learning.

The first of these areas is *group learning* (cooperative and collaborative learning methods; See chapter 11). Collaborative learning follows a social constructivist model of learning, namely, that knowledge is created through interaction between people that builds on prior knowledge, resulting in "critical thinking, problem solving, sense making and personal transformation, the social construction of knowledge-exploration, discussion, debate and criticism of ideas." (Boud D., Ruth C., & Sampson J., 2001). Team learning not only incorporates elements of cooperative learning (Johnson and Johnson, 1999) such as positive inter-dependence and face-to-face interaction, but also includes a trained team leader who holds each member accountable, facilitates decision making and provides feedback on how the team is performing.

The second contribution comes from the area of *reciprocal teaching* (Palincsar & Brown, 1984; Brown & Palincsar, 1989) and the power of *explanatory knowledge* (Coleman, 1998; Coleman, Brown, & Rivkin, 1997). In reciprocal teaching, instructional tasks are designed by studying and breaking down the strategies used by successful learners and then using these to guide the learning by novices. Research on explanatory knowledge concludes that students need to reflect on their learning and develop interpersonal communication skills as a part of understanding. Coleman's results are compellingly clear: a student who anticipates the need to make a subsequent explanation about something which is being learned will learn it better in the first place. In team learning, promoting reflective practice helps students understand that true learning comes from discussing the basis for one's answers and conclusions rather than memorizing the answers (Chambers & Abrami, 1991).

The third area that informs team learning is based on the educational theories attributed to Lev Vygotsky. Vygotsky believed strongly that community was necessary in order for students to "make meaning" (Vygotsky, 1978, 1985). The two critical components in Vygotsky's model are: (1) an individual who has a higher level of ability than the learner with respect to the particular idea or activity that needs to be learned (the MKO, or More Knowledgeable Other), and (2) tasks designed to press the learner to a reasonable expectation of achievement or understanding by providing appropriate assistance (scaffolding) that is easily removed as learning gains are achieved (these are tasks within the Zone of Proximal Development, or ZPD). ZPD is the most important concept for designing appropriate instructional materials. Tasks that are merely drill problems that do not require ideas to be synthesized or creative work to be done fall below the threshold for ZPD tasks; while, for instance, applying the ideas derived from reading Lavoisier in the original French to solving structural chemistry problems are likely to be beyond a reasonable ZPD.

The fourth area, *studio instruction,* is the least well examined in science teaching and learning even though it is a part of the implicit framework that describes team learning (Rieber, 2000). The essence of *studio instruction* is to have students generate materials that represent their learning. In the traditional artist's studio, artifacts that represent student learning are writing, painting, musical composition, sculpture, etc. In the research laboratory, experimental results such as new compounds, new separation methods etc., represent products of learning; they are documented and ultimately legitimized by subjecting them to peer review and critique. In a problem solving team, a student’s particular solution to a problem serves as a product of learning. These products that clearly represent student learning then become an object of study, peer review and critique, and the group learns from the collective understanding derived from individual interpretation of common tasks. In a studio format, tasks need to be sufficiently sophisticated that errors and misunderstandings emerge as a topic of conversation but are not so demanding that transfer of learning is impossible (Bransford and Schwartz, 1999). Engineering programs have developed sophisticated instructional spaces to support studio instruction (Wilson, 1994), and a few chemistry departments have begun to follow suit (Bailey, Kulinowski & Paradis, 1998; Apple & Cutler, 1999; Sweeder, et al., 2003; Blunt, et al., 2003; Gottfried, et al., 2003).

Breaking the tradition of [only] centralized authority in teaching and learning coincides with society’s demands for increasing the diversity of people who are prepared to do (or understand) science and technology. This is fortunate, because many believe that this increase can be accomplished by designing classrooms that foster success both broadly and inclusively. As a case in point, Seymour and Hewitt (1997) showed that “the most effective way to improve retention among women and students of color, and to build their numbers over the longer term, is to improve the quality of the learning experience for all students—including non-science majors who wish to study science and mathematics as part of their overall education.” They also found that while almost all students value collaborative learning, students from underrepresented groups “appreciate it more and miss it when [it is] unavailable.” Their research identified interactive collaborative learning as key to improving student performance. Triesman (1992) showed that students often fail to excel in science and mathematics because they do not know how to work effectively with peers to “create a community for themselves based on shared interest and common professional goals.” He found that remedial programs and those specifically targeted at minority groups often do not increase success rates. Indeed, Steele (Steele, 2000) has argued convincingly that institutional identification based on deficiency, while well-intended, becomes a self-fulfilling prophecy whose victims “under-perform” to prescribed institutional stereotype and bias. Thus programs designed to improve learning must include all students.

Models for Team Learning in Chemistry

Team learning is not a single model. It covers a range of different but related approaches. Two of these are described in this section.

A. Peer-Led Team Learning (PLTL)

Introduction. The PLTL workshop model (Gosser & Roth, 1998; Sarquis, et al., 2001; Woodward, Gosser, & Weiner, 1993) was developed, in part, to address faculty concerns about student learning and high attrition rates in introductory chemistry courses by providing an environment in which students work in problem solving teams to develop their conceptual understanding and learn to communicate scientific ideas (Gosser, et al., 1996; for an overview of the instructional model, see Sarquis, et al., 2001. A comprehensive report of the research and development work on the model is available, Gosser, et al., 2001).

The core of the PLTL approach is a weekly 1.5-2 hour peer-led workshop, where students interact to solve carefully structured problems under the guidance of a peer leader. In a typical workshop, six to eight students work as a team to solve carefully structured problems. The Peer leader clarifies goals, ensures that team members engage with the materials and with each other, builds commitment and confidence, and encourages debate and discussion. A good leader keeps the group focused on seeking, announcements of answers that short-circuit thought processes. The peer-leader is central to the modelwhich is not remedial and is targeted at all students (Sarquis et al., 2001). PLTL is a powerful addition to instructional settings, and is especially useful in settings that do not routinely offer recitation or discussion sessions as a part of their courses. PLTL has also been successfully used to replace graduate student led recitations (Tien, Roth and Kampmeier , 2002). Undergraduate peer leaders are students who have been identified as successful in the course, have been out of the course for at least one semester, and who also demonstrate superior interpersonal skills and leadership potential. PLTL has been tested and successfully implemented in chemistry, biology, physics and mathematics courses at a wide variety of institutions (http://www.pltl.org). In 2002, approximately 15,000 students were enrolled in PLTL courses offered at more than one hundred diverse institutions (Varma-Nelson and Gosser, 2004).

In PLTL, the instructors have been routinely responsible for constructing workshop units and for identifying the first cohort of undergraduate peer leaders. Answer keys are not provided to the students or the leaders. The students are expected to develop confidence in the solution through debate, discussion and persuasion. The emphasis is placed on the process of finding and evaluating several possible answers rather than uncovering the single correct answer . A good PLTL workshop unit should promote brainstorming and teach students to verbally articulate scientific concepts. Ideally, the workshops should end with summary of the big ideas that were arrived at, with a the general accuracy of these conclusions directed by the guiding hand of the peer leader. Reflection by the workshop students on any changes in their own understanding of those concepts is particularly useful, especially when alternative conceptions for the ideas dealt with are common.

Often PLTL sessions do not involve any graded work or earned credit, so providing a strong and clear added value to the experience is paramount. Without the usual rewards, however, student preparation can be variable. Peer leaders, for example, when surveyed, commonly report lack of student preparation for the workshops (Gafney, 2001). Assigning preliminary readings, appropriate end of the chapter problems and self-tests are methods used to deal with the problem. Short pre-workshop quizzes are a good way to encourage preparation as well..

Tested workshop materials are available in chemistry (Gosser, Strozak, & Cracolice, 2001; Varma-Nelson & Cracolice, 2001; and Kampmeier, Varma-Nelson, & Wedegaertner, 2001). Using existing materials is likely to reduce some initial barriers encountered in implementing the PLTL model because it reduces the work of the initial set-up. Many instructors choose to develop new materials, or modify existing ones, to suit their own student populations and course content.

Sample Workshop Problems

The following are two problems taken from PLTL Organic Chemistry (Kampmeier, Varma-Nelson and Wedegaertner, 2001) that work well in a workshop setting and can be used in beginning Organic Chemistry classes. Also included in each case are the instructions given to the student leader.

1. Two isomeric compounds **A** and **B** are known to each have a monosubstituted benzene ring (C_6H_5-). Both have the formula $C_6H_5C_3H_5O_2$ and both are insoluble in water. However, when they are treated with dilute NaOH, A dissolves but B does not. Give structures for **A** and **B** *consistent* with this information. **Explain your reasoning**.

Discussion: Puzzle problems are great Workshop problems. Here is one way to proceed. Ask the students to read the problem carefully to find out what they are supposed to do (figure out structures that are consistent with the given observations and the rules of structure). The leader can volunteer to serve as scribe. Ask the students to reread the problem to find the observations. (This is important because everyone can participate.) Now, take the observations one by one, and ask the students to tell what can be deduced about structure from each observation. (Pick respondents carefully, keeping the better students for the tougher observations.) Then, encourage the group to collect the deductions to make larger deductions, and so on, until the problem is solved.

Beginning students tend to try to solve the structure problems all at once, taking all of the data in one big gulp. They also tend to jump to conclusions. They guess a structure on the basis of one observation, for example, (C_5H_{12} = $CH_3(CH_2)_3CH_3$, and then will not let go of it even when the structure is excluded by subsequent observations. It is always much better to have multiple hypotheses (there are three C_5H_{12}'s); then it is psychologically easy to exclude hypotheses.

Take Home Points. Solving problems such as these requires students to know the empirical facts (this structure has these properties or vice versa) and to connect the facts in a purposeful manner. Connecting individual deductions to make larger deductions is both logical and creative. It is distinctly higher order thinking than knowing the simple observation-deduction pairs

2. Although we discussed the data of tetrahedral carbon as proposed by Van't Hoff and Le Bel, square planar carbon is also a possible structure. Show how this structure can be eliminated by considering CH_2Cl_2 and CH_2BrCl as examples of disubstituted methanes.

a. How many isomers would be present in each instance if the carbon had a square planar structure?

b. How many isomers are possible in each instance if the carbon is tetrahedral?

Consider CHBrClF as an example of a trisubstituted methane.

c. How many isomers would be possible if the carbon atom were square planar?

d. How many isomers are possible for CHBrClF if carbon is tetrahedral?

The experimental observations are:

CH_2Cl_2	one isomer
CH_2BrCl	one isomer
CHBrClF	two isomers

Discussion: This would be a good problem to solve by dividing the group into smaller groups. Students can count isomers and then compare and debate answers.

This is a great Workshop problem because it gets directly at the epistemological issues. How is it that we know what we think we know? This problem emphasizes that there is a logical, rigorous way of eliminating the hypothesis that tetravalent carbon has a square planar geometry. The tetrahedral hypothesis is shown to be consistent with observation. The logic does not prove that tetravalent carbon is tetrahedral, but it does prove that it is not square planar.

Take-Home Point. We think what we think because of a trail of logic, not because somebody said it.

Outcomes. The national PLTL Project has engaged in "action research" based evaluation, in which results have been fed directly back to the programs under study in order to refine and improve the model. Data collection methods have included focus groups, surveys, structured phone interviews, reports from faculty on student grades, site visits and observations by the PLTL project evaluator Leo Gafney (2001).

Critical components for implementation. This evaluation has identified six critical components for successful integration of the PLTL model into a course. These components have been repeatedly found to contribute to successful student performance, while their absence has led to problems in implementation and lack of gains in student performance and retention. These critical components are:

1. The workshops are integral to the course, not an optional add-on.
2. The workshop materials are challenging, intended to encourage active learning and to work with groups.
3. The workshop leaders are well trained and closely supervised, with attention to knowledge of chemistry and teaching/learning techniques.
4. The faculty teaching the course are closely involved with the workshops and the workshop leaders.
5. The organizational arrangements including the size of the group, space, time, noise level, etc. are structured to promote learning.
6. Workshops are supported by the department and institution.

Exam performance. The PLTL Workshop model has had a positive impact on student attitude and success in the study of science and mathematics. Faculty members have compared the performance of non-Workshop and Workshop sections of their classes in a given semester or between semesters. Percent success data across a wide range of courses and institutions demonstrate that students who participate in PLTL Workshops earn better grades than those who do not (or who may participate in other structures such as traditional recitations).

One study at Saint Xavier University (SXU) by Varma-Nelson demonstrated that in a class taken primarily by nursing majors, 99% of whom were women, the student success and retention rate increased by more than 10% and performance on a national standardized ACS exam improved when the lecture time was reduced from four hours to 2.5 hours and the remaining 1.5 hours were used for PLTL workshops. The results on the ACS exam also indicate that content covereage was not compromised.

Tien, Roth and Kampmeier (2002) conducted a study on groups of students who were in Jack Kampmeier's traditional organic chemistry course from 1992 to 1994 with those who were involved in PLTL Workshop from 1996 to 1999. Although the control and treatment sections were not taught in the same year, they were similar in many ways. The same instructor taught the course, with the same textbook, lecture style, class size and same level of difficulty. It was found that the workshop participants outperformed the control group on exams in all cases. For overall means, the scores were significantly different with $p < 0.01$. When broken down by gender and ethnicity, the results show that all PLTL groups outperformed their counterparts in the more traditional course. While such rigorous statistical analyses have not been performed in all cases, at least 20 similar studies have been conducted involving PLTL workshops at other institutions involving several disciplines (http://www.pltl.org). As stated by Lyle and Robinson (2003) "although there may be flaws in a study, if the study is repeated, taking into account the flaws that have arisen and the same general results occur, the results can be considered useful."

Student satisfaction. Surveys completed by more than 700 respondents at nine institutions using PLTL reveal that when the method is introduced with fidelity to the model, students place a high value on the workshops and have found them be helpful to their learning. A total of 82% of respondents stated that they would recommend the workshop course to their peers, and the majority felt comfortable asking questions and report that their leader was well prepared to effectively facilitate the workshops.

Leader reflections. As apparent in the quotes the leaders assert that their involvement in the PLTL workshops has given them confidence to do more science, improved their presentation skills, and improved their understanding of the teaching and learning process. The following are quotes taken from a study done on former leaders who worked with one of us (PVN) at Saint Xavier University (SXU):

"As a leader, I gained the knowledge and confidence I needed to pursue a career in pharmacy. During many courses in pharmacy school, I became known as a group leader"

"That's always exciting to see - the transition from "this stuff is just too hard and there's no way I can understand it" and a self-defeatist attitude to these same people explaining the concept to someone else because now they understand it and own it, they teach it now because they've gone through the process."

"This taught me that sometimes students need to see things explained in a different manner from the textbook or lecture notes and handouts…….."

> "It helped me be more at ease speaking in front of a group, and able to express myself when everyone is looking at me."
>
> "Group Setting: I used to work alone. I never studied with anyone, until workshops. Then I took biochemistry after organic. It was really a tough course. It was the first time it was held. But I noticed that when I got together with friends, it was as if we were running a workshop. A lot of people don't realize how much it affected them, because they don't think about it. But when you think about changes in the way you learn, you find that you have changed."

"My involvement in the project remains one of the most impressive entries in my resume and has come up in every job interview I've had since leaving St. Xavier U."

For further leader reflections see essays written by former student leaders from several institutions in the "Peer-Led Team Learning: A Guidebook"(Gosser, et. Al. 2001).

B. Structured Study Groups (SSG) at the University of Michigan

Introduction. Since 1994, a cohort of 120-160 first-year students earns Honors credit in Supplemental Instruction (SI) sessions attached to the 1000-student course of standard coursework and examinations in the organic chemistry based Structure and Reactivity courses (Ege, Coppola & Lawton, 1997; Coppola, Ege & Lawton, 1997). We developed this modified supplemental instruction option in lieu of a separate honors section of the course because we felt that first-term students could not judge whether or not an honors section of organic chemistry would be appropriate (Coppola, Daniels & Pontrello, 2001). In this format, students are able to experiment with taking the course for honors credit for three weeks and then drop the SSG sessions and take the course for regular credit without changing their course schedule. We believe that an honors option should broaden a student's experience with respect to the regular course. Because SSG honors students take the same recitation sections, labs, and exams as non-SSG students, coursework for honors and non-honors credits can be compared easily. In addition, an SSG honors option saves a faculty teaching assignment that otherwise would be required for a separate honors section. Finally, the SSG option is not restricted to students in the honors program. Any student who elects and satisfactorily completes the SSG option is awarded honors credit.

SSG leaders are juniors and seniors who demonstrated teaching skills when they were SSG students. Indeed, the SSG assignments permit students to demonstrate their teaching potential with the idea that they might become SSG leaders. SSG leaders identify prospective future leaders from among their students and justify their choices to the faculty coordinator. Identified students submit essays to the coordinator as part of the selection process for SSG leaders. Leaders are not necessarily chemistry majors; of 68 student leaders from 1994 to 2003, 37 have been majors in chemistry, 16 in biochemistry, 4 in biology, 2 in chemical engineering, and 9 in cellular and molecular biology.

As former SSG participants, SSG leaders begin with a strong sense of the program. SSG leaders attend weekly lunchtime meetings with the faculty coordinator to reflect on their teaching, anticipate teaching issues, and determine the evaluation criteria for the week. Each week a different leader leads a discussion on teaching and learning and then records and distributes the outcomes and recommendations for the group. Leaders continue to discuss teaching issues throughout the week on the SSG leaders' listserv.

SSGs are generally 15-20 students in size. While this is larger than the usual optimum for team size, the SSG sessions structure numerous small group (2-4 student) interactions with high accountability, particularly peer review. SSG sessions follow a detailed curriculum that encourages discussion and explanation activities that lead to deep mastery of organic chemistry. the first session for example, SSG leaders: 1) lead an ice-breaker activity on reciprocal teaching, 2) have students go to the blackboard to teach one another how to decode line formulas, 3) take their group to the library to explore chemistry journals, and 4) present a short introduction to proper citation format. From the first version, created in 1994, all of the instructional materials have been constructed and subsequently modified by one of us (BPC) in full collaborative partnership with undergraduate student leaders.

The first assignment. Beginning with the first homework assignment, SSG leaders have students apply the concepts they are learning to new material using a creative task. For their first assignment for example, leaders ask that students pick a molecule with 10-13 carbon atoms from a chemistry journal, construct five new (rational) molecules with the same formula, rank the molecules based on selected properties (e.g., magnitude of dipole moment, boiling point, and solubility) and write out rationales for their rankings. The student work for this assignment must include a statement putting the journal article into context, a copy of the journal page from which the example came, and a properly formatted citation. In other assignments, leaders ask students to format an appropriate quiz problem from the new material. The second SSG session builds on this homework assignment. Students must submit one copy of their homework to their leader and the other copies are distributed into the group for two rounds of peer review. SSG leaders create an assessment rubric, which for the first assignment might address whether the molecules fit the prescribed criteria, whether the format and information are appropriate to the class level, and whether the citation is formatted correctly. Peer review is a time of in-depth discussions and learning; the first round of review can take up to an hour. During this time, the leader circulates, noting common issues that arise, sending students with interesting examples to the board, and otherwise facilitating a usually-raucous discussion predicated on one question: is this work I am looking at correct or isn't it? In the peer review, students must grapple with ideas in a classmate's homework that conflict with their own work and through discussion figure out where errors in understanding the material or process have occurred. This grappling gives SSG students the opportunity to make, recognize, and correct their own errors. The reviews are returned to the originator (the review is a piece of paper with "yes" and "no" answers that have been circled), who has a chance to decide whether to make any changes to the original assignment. The SSG leader collects the edited assignments and peer reviews and uses them in evaluating student performance.

One of the overarching goals of the SSG honors sessions is for students to develop the ability to create meaning from new and unfamiliar chemical information, especially scientific information from the primary literature. In the capstone assignment, SSG leaders ask students to read original journal articles, generate and discuss questions that they would ask the author about the article, and meet with the author in a 1-2 hour session to ask their questions. In addition, writing assignments are used (e.g., "create an analogy for chemical phenomenon"), as well as an introduction to research ethics that involves reading and then writing a position paper on a subject of topical interest to science or science education (e.g., the Kansas State Board of Education decision).

The SSG leaders provide feedback to the students on their work and participation in the weekly sessions. They use this feedback to assign grades for the SSG sessions based on a scale of O (outstanding), S (satisfactory), and U (unsatisfactory). Course grades for SSG students are based on a two-part scheme. The base grade for an SSG student is determined in the same manner as it is for a non-SSG student (the exam scores for the course). In order to receive the base grade with an honors designation, students need to receive an "S" to "O" average from their SSG leader. A "U" average results in the student receiving the honors designation, but the base grade is reduced. In the research-oriented section of the course, there are two layers of SSG assignments. For the first layer, SSG leaders help design and then implement - a series of tasks that are comparable to those in the SSG sections for the larger course. For the second layer, SSG leaders help students create and carry out projects. In one of these term-long projects students construct a written and HTML resource on advanced chemical transformations that are incorporated into the course website. Reading journal articles, understanding the chemical transformations described in them, and then creating animated reaction mechanisms and interactive assignments for their classmates causes the students to think like teachers. The multimedia text is fully owned by the students and, as a class-sized group, they must seek out each other's expertise in order to understand the material and complete the project. The SSG leaders in the project-oriented section do a great deal of work that would be impossible for one faculty member to do, including creating lessons on HTML authoring, locating appropriate software and managing the logistically-demanding task of coordinating the efforts of 100 individuals working on a single website project.

Conclusion

Team learning is in many respects a "second generation" instructional strategy in that it draws together a powerful collection of pedagogies such as *group learning, reciprocal teaching, Vygotsky's learning theory* and *studio instruction*. Students bring their work on problems to classes structured to promote reasonable extension of ideas. Theoretically, students are doing generative (studio) work on problems that push them past what they might be able to do individually (their *ZPD*), and they reconvene in groups (group learning) in order to present and aid each other through the navigable steps of the problem-solving process (reciprocal teaching). They engage such practices as explanation, conversation, peer review and critique under the watchful eye of a leader.

Learning gains derived from Team Learning include increases in subject matter mastery as well as higher order cognitive skills. In addition, an intimate and trusting social environment creates a network for support within the students' university experiences. Finally, team leaders develop skills in both management and instructional development and implementation.

SUGGESTED READINGS:

Boud, D., Cohen, R., Sampson, J. (2001). *Peer Learning in Higher Education*. Sterling, VA: Stylus Publishing. The first half of the book sets a broad historical context, and synthesizes from the literature a nice review of designing peer learning environments, describing multiple approaches, discussing management issues, and covering learning and assessment topics. The second half of the book looks at a series of elaborated case studies: in MBA and Law School, and then a number of different Instructional Technology examples where distance and other computer-mediated learning is integrated with face-to-face activities. There are a few unique advantages in this particular book. First, the perspective is from adult education rather than elementary education, so the methodologies and discussion can be more easily understood in an advanced context. Second, the editors are knowledgeable and contribute about 50% of the text, and their experience as faculty members at the University of Technology, Sydney, is apparent. Third, there is a strong, selective and not-overwhelming research base to each chapter.

Jaques, D.(2000). *Learning in Groups* (3rd ed.). Sterling, VA: Stylus Publishing. This book is written for people teaching college tutorials in England but is an excellent resource for anyone who is involved in higher education. It is easy to read and offers many practical tips on how to use groups in teaching. The book is written in a way that permits flexibility of use. Instead of starting at the beginning one may start by reading chapter six, which provides suggestions for structured activities that can be used in groups. For each activity there is a discussion on how to set up the task and also its benefits and drawbacks. The appendix has a list of problems one may encounter in group activities and possible solutions. The earlier chapters in the book discuss learning theory and theories about group behavior and what is known about communication in groups. Chapter one has an excellent discussion about how the characteristics of a group change as its size increases. Chapter nine which is about assessment is also very useful. There is an extensive list of references at the end of the book for further reading.

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