A Course To Prepare Peer Leaders To Implement a Student-Assisted Learning Method

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What is it that "good teachers" know about helping students learn chemistry? How can this knowledge be taught to novice instructors? At the University of Rochester, we have been preparing undergraduate students to take on a new role in the context of a student-assisted learning environment. The model is appropriate for training individuals for leadership roles in traditional and nontraditional classrooms (e.g., guided inquiry, collaborative learning, active learning) and has implications for teaching assistant training and faculty development.

Peer-Led Team Learning (PLTL) is a method of student-assisted learning in which a successful undergraduate student guides a team of 6–8 students engaged in solving problems developed by the course instructor *(1–4).* This activity is referred to as a "PLTL Workshop" (or simply Workshop) to distinguish it from a conventional recitation session. The central activity in a PLTL Workshop is discussion and debate of the concepts and ideas that form the basis for solving the problems. The "peer leader" is a facilitator of that discussion, not a teacher in the traditional sense of lecturing or demonstrating how to solve the problem. The PLTL Workshop includes the following components: (i) the Workshops are integral to the course; (ii) the Workshop materials are challenging and encourage collaborative problem solving; (iii) the Workshop peer leaders are well trained and closely supervised, with attention to content knowledge and teaching and learning techniques; and (iv) the faculty teaching the course are closely involved with the Workshop and the Workshop leaders *(5).*

"Before and after" studies in several different types of institutions have demonstrated that participation in PLTL Workshops leads to significant improvements in student grades, retention rates, and attitudes in undergraduate chemistry courses *(3, 6).* We compared student performance in traditional recitation sections versus the Workshop over an eight-year span in the first-semester organic chemistry course. We observe statistically significant improvements in retention for all students (66.1% Recitation versus 77.0% Workshop) as well as increases for all subgroups (male/female, majority/underrepresented minority) *(7).* Comparable improvements in retention for all students have been observed in different science courses at a broad range of institutions *(8).* Results from an adaptation of the Student Assessment of Learning Gains questionnaire *(9)* indicate that students believe that the Workshop experience is the most important aid to learning organic chemistry. Other studies show that the leaders' careful cultivation of a supportive environment influences students' perceived competence, intrinsic motivation, and course performance *(10, 11).*

Based on our experiences and observations and those of the national PLTL project, the preparation of the peer leaders is key to an effective Workshop. The undergraduate peer leaders are students who have demonstrated content mastery in the course the previous year. Nevertheless, a mechanism is necessary to prepare them for the transition from the student role into a new role as peer leader of a small problem-solving team. At our institution, the peer leaders enroll in a credit-bearing course (2 credits) that builds bridges from the educational research literature to specific classroom applications. The course is co-taught by an education specialist and the professor who teaches the chemistry course. The collaborative instructional model provides a mechanism for the teachers to integrate their respective expertise and publicly endorses the value of understanding pedagogy *and* chemistry *(12).* The course goal is to arm the peer leaders with classroom and pedagogical skills to facilitate their students' learning in an interactive team environment. Since the peer leaders meet weekly throughout the semester in which they work as Workshop leaders, the course has special relevance.

The structure of the training course builds upon two fundamental principles: (i) there is a reliable, well-established research literature about students and learning; and (ii) abstract pedagogical ideas become robust and practical when they are analyzed and applied in specific problem-solving activities. The substance of the training course centers on classroom knowledge and pedagogical content knowledge. Classroom knowledge (CK) refers to specific knowledge of the students and the classroom environment and includes awareness of motivation and interpersonal dynamics *(13–15).* Pedagogical content knowledge (PCK) integrates pedagogical ideas with the subject matter and refers to knowing the content and how to teach it to a diverse group of students *(16, 17).* As such, PCK involves being alert to ideas students bring into the classroom (including prior conceptions and misconceptions), being aware of problems students encounter in learning the material, and having a toolkit of effective teaching tactics for various situations and contexts.[1] Experienced instructors have built their CK and PCK structures over time and through *reflection-in-action (18).* Since novice leaders do not have the luxuries of time and experience to develop their own pedagogical framework, the training course educates the peer leaders regarding CK and PCK issues in the context of the specific chemistry Workshop. In this article we describe our leader training course for introductory organic chemistry.[2, 3] While the training course focuses on the preparation of undergraduates for their new role in teaching and learning, we have used the same course to prepare graduate students and postdoctoral fellows to be peer leaders. Our experience has been so positive that we believe that a comparable course would be beneficial to prepare graduate student teaching assistants, as well as future faculty, for other roles in teaching and learning.[4]

Training Course Format

The training course is designed to help peer leaders understand and internalize abstract pedagogical ideas on a practical level. Each class is preceded by assigned course readings from the *Handbook for Team Leaders (19)* or additional supplementary articles. The readings are organized so that they address issues that the peer leaders will encounter. The leaders may have even started to formulate some ideas of their own as a result of interactions and experiences in the Workshops that they participated in as students. During the weekly training course discussions, the peer leaders then sharpen their understanding of the concepts from the readings and begin to internalize them. The leaders also figure out how to make use of the CK and PCK ideas in the Workshop environment and, where appropriate, the next Workshop and upcoming set of problems. Application of the ideas begins in the whole-class discussion and continues as leaders put the ideas into practice with their students in their individual Workshops; subsequent workshops provide new challenges and opportunities for the peer leaders to refine and test their developing insights. Weekly journals enable the peer leaders to reflect upon the pedagogical ideas and their applications in the Workshop, and provide a mechanism for experienced peer leaders to provide one-on-one support to the new peer leaders by responding to the issues raised. In addition, the journals give the instructors a window into what is going on in each of the Workshop sections and serve as a springboard for discussion and feedback at the beginning of each weekly class.

Finally, it is essential that peer leaders know how to solve the Workshop problems, and the final portion of each class is devoted to rehearsing the Workshop problems. In general,

CAS 352 Issues in Group Leadership

Goal:
This course is designed to provide training and support for Workshop leaders. Discussions will include both theoretical and practical aspects of leading an organic chemistry Workshop.

Text: *Peer-Led Team Learning: A Handbook for Team Leaders (19)*. Additional readings from the educational literature will be distributed in class.

Requirements and Grading:
1) Class attendance, participation, assignments (~50%)
2) Electronic journal (~25%) *Each week*, you will forward your recap and reflections for us to get a sense of what is going on in the Workshop (e.g., what you did, how your students responded, how the problems worked, what went well, what could be improved, interactions among the students, etc.) and for you to get feedback from an experienced leader.
3) Course project (~25%) The course project is designed to offer you and a partner the opportunity to explore an educational topic of special interest to you. Your exploration will culminate in a 5–7 page written report and a poster presentation.

Section	Topic	Reading	Assignment
Classroom knowledge: knowing the environment	The Workshop Philosophy; The role of the leader	Ch 1–2 Handbook; Tobias *(20)*; The PLTL Workshop Project Newsletter *(21)*	#1: Beliefs about teaching and learning
	Getting a group started	Ch.3 Handbook; Towns *(22)*	
Classroom knowledge: knowing your students	Student development	Ch. 6 Handbook; Perry *(23)*	
	Diversity	Ch. 7 Handbook; Gallos *(24)*; Rosser *(25)*	# 2: Observation of a workshop
	Motivation	Ryan & Deci *(26)*	
The Bridge: classroom knowledge & pedagogical content knowledge	Cognitive apprenticeship	Collins, Brown, & Holum *(27)*	
Pedagogical content knowledge	Reciprocal questioning	King *(28)*	# 3: Midterm feedback
	Alternative conceptions	Henderleiter, et al. *(29)*	
	Problem solving	Herron *(30)*	
Consolidation	Metacognition	Rickey & Stacy *(31)*	# 4: Self-assessment of teaching style
	Conceptual change	Hewson *(32)*	
	Constructivist teaching	Glatthorn & Coble *(33)*	

Figure 1. Training course syllabus.

our peer leaders are not chemistry majors; they need a structure for recollecting the substance of the problems and building confidence in their understanding. Armed with ideas from the CK and PCK discussions, the peer leaders work in teams to brainstorm ways to solve the problems in the next Workshop. The chemistry instructor may answer questions, explain a difficult idea, emphasize the logic of the problem (i.e., model his thought process), identify common misconceptions or errors, share the "take-home points" behind the problem, and point out connections to previously learned material. The instructor does not give his solutions to the problems. Just as we want our leaders to model their thinking and scaffold their students' learning, we try to do the same in our training efforts. Ultimately, the leaders construct their own answers to the problems and design their own approaches to facilitate the work on the problems.

Training Course Content

At the beginning of the semester, a one-day orientation and the training course focus primarily on CK concerns to prepare the leader to *support the individual learner*. As the semester progresses, PCK issues are introduced to prepare the leader to *make thinking visible*. The training course syllabus is shown in Figure 1. After the one-semester training course, a subsequent leader training course accompanying the second-semester organic chemistry course focuses primarily on content knowledge and pedagogical chemical knowledge, as leaders are familiar and confident with running a Workshop.

The one-day orientation introduces peer leaders to CK ideas related to knowledge of the Workshop environment (e.g., organizing group work and group dynamics) and knowledge of the students (e.g., diversity). During the semester, the training course introduces additional CK topics such as student development and motivation, but also revisits ideas discussed previously. The CK and PCK elements of the course are unified by a consistent presentation of the tactics of cognitive apprenticeship *(27),* an alternative instructional model to replace traditional teacher-centered models for lecture and recitation.

Classroom Knowledge: Motivation

Supporting the individual learner encompasses understanding motivation and the factors that can promote self-motivation. The vitality and productivity of the Workshop depends on students' willingness to engage with the material and with each other as they work on the problems. Thus, the peer leaders need to be aware of conditions that facilitate or undermine intrinsic motivation.

Peer leaders read an overview of Deci and Ryan's motivation theory *(26)* that introduces them to the concept of self-determination. Self-determination theory focuses on the social and environmental conditions that affect intrinsic motivation. In class, the peer leaders explore three aspects that influence intrinsic motivation (competence, autonomy, and relatedness) and brainstorm how they can promote each factor. While an introductory science class is typically characterized by a lack of community *(20)*, the Workshop structure is motivating because students work together in a small group. Collegiality develops as the semester progresses, and students in a Workshop often organize additional sessions outside of the class. In addition, the very nature of the Workshop activity promotes competence and autonomy as it engages students with conceptual problems and allows them to find their own solutions. An autonomy-supportive peer leader can also provide students with opportunities for choice, such as electing how to proceed in solving a problem (instead of dictating a method) or choosing to work as one large group or in groups of two.

To apply self-determination theory, one activity asks peer leaders to evaluate their reaction to various instructor responses to an impasse (e.g., "I see you're having trouble with Concept X. You'll have to know this for the exam."; "I see we're all getting stuck on Concept X. This tends to trip students up."; "I see you're having some trouble. This is usually pretty easy for people.") The ensuing discussion compels peer leaders to consider the ramifications of their behavior as it relates to students' competence, autonomy, and relatedness. Another training activity introduces case studies of situations in the Workshop. For instance, one peer leader observed diminished participation in the Workshop and found that students directed their questions to him rather than to the other students. The leader attributed this behavior to the students' perception that the leader had the "one right answer", a perception that undercut the students' competency and autonomy *(34).* In the class, the leaders dissect the situations and formulate possible approaches to foster an environment that encourages participation. A favorite leader tactic to emphasize the authoritative responsibility of the students is to simply leave the room for a while.

Cognitive Apprenticeship

Cognitive apprenticeship serves as a bridge linking classroom knowledge and pedagogical content knowledge. Classroom knowledge includes an awareness of various instructional models. We introduce cognitive apprenticeship early in the training course as a powerful alternative to the transmission model of instruction with which the peer leaders are most familiar. This is an essential component of a strategy for change; without a viable alternative, the peer leaders will revert to familiar modes of instruction. The student experience in undergraduate science courses is often the "gas station model"; students come into the classroom to be filled with the knowledge the instructor pumps out. The overarching idea of cognitive apprenticeship is to make one's thinking processes visible to the students to adopt. In the Workshop, the peer leader first models expert practice by providing structures or ways of thinking during problem solving (including one's logic, rationale, and decision making processes). The leader then scaffolds and coaches to provide the necessary support for the students to carry out the task, and finally fades (or, gradually removes support) once students internalize the process and start to demonstrate mastery.

Peer leaders read a paper providing a description of cognitive apprenticeship *(27).* In the training class, the peer leaders discuss the main points of the instructional model and implications for their role, that is, how to implement a model of apprenticeship in the organic chemistry Workshop. The leaders consider such classroom tactics as prompting students to articulate and reflect upon their ideas (to make their thinking visible to themselves, to each other, and to the leader for diagnosis and appropriate guidance) and the value of having leaders structure the discussion to make "expert" thinking visible to the students.

Up to this point, much of the discussion focuses on abstract ways of thinking about cognitive apprenticeship in the Workshop setting. To contextualize the discussion and bridge to pedagogical chemical knowledge, the leaders are given the following problem *(35)* from an upcoming Workshop in which the instructor has crafted the problem to reveal the expert approach:

> Three carboxylic acids, $C_2H_2(CO_2H)_2$, **I**, **J**, and **K**, react with H_2 in the presence of a catalyst to give two dicarboxylic acids, **L** and **M**, with formulas $C_2H_4(CO_2H)_2$. **I** and **J** give the same dicarboxylic acid **L**. Compound **K** reacts to form compound **M**. Give structures for compounds **I–M** that are consistent with the experimental observations. Explain your reasoning.

Observation	Deduction
1.	1.
2.	2.
3.	3.
4.	4.
5.	5.

The peer leaders are asked to consider how their students will respond after reading through the problem. Based on his PCK, the course instructor shares the epistemological problem; many students wonder how they are supposed to know the structures from the given information. Drawing from their own experiences, the leaders remember that students will think the problem is hard: hard for them to know where to begin to answer the question, hard to organize different bits of information, hard to put the pieces together, and hard to explain their reasoning. The peer leaders are asked to reflect on their own novice thinking processes and some of the common missteps and errors. The discussion evolves to the expert approach. The experienced problem solver breaks down the problem into manageable chunks (i.e., observations) and then processes the observations (i.e., makes appropriate deductions).

The observation–deduction format becomes a framework for structuring the work and the underlying thinking process that will lead to a solution. For example, one observation is: compounds **I**, **J**, and **K** have the chemical formula $C_2H_2(CO_2H)_2$. One key deduction from this observation is that the compounds are unsaturated; thus, each structure contains a double bond. Another observation is the chemical reaction: **I** (or **J**) + H_2 → **L**. This observation leads to the deductions that compounds **I** and **J** possess the same constitutional structure and must, therefore, be stereoisomers. The peer leader can scaffold the group discussion by asking the students to identify the individual experimental observations and can record those observations on the board. The next step is to get the students to think about the implication of each observation. While some students may have difficulty initially making appropriate deductions, everyone is able to participate in the observation phase. Finally, the peer leader can encourage students to propose "partial hypotheses" and establish partial structures from the deductions, write out possible structures (i.e., multiple hypotheses), eliminate structures based on their inferences, and consider possible ambiguities to formulate the final answer.

The underlying thinking processes use the fundamental "if, then" and "if not, then not" syllogisms and invoke observation and deduction skills, all of which require guidance and practice for students to master. The cognitive apprenticeship model provides a framework for the peer leaders to think about their role in helping students develop and practice expert thinking, including deconstructing complex issues into manageable pieces, recognizing patterns and connections in complexity, and reasoning from experimental observations to reliable conclusions. Above all, it models a logical way to analyze and solve a problem, in contrast to the novices' tendencies toward random attacks and wild guesses.

Pedagogical Content Knowledge: Problem Solving

The fundamental idea of cognitive apprenticeship, to make thinking visible, is extended and made specific in the context of PCK. While the observation–deduction format was appropriate for the previous problem, different problems require different kinds of thinking or PCK.

The organic chemistry course is an exploration of the relationships among structure, properties, and reactivity of organic compounds. Students are required to construct an empirical database *and* conceptual understanding, with the ultimate goals of being able to think independently and productively to solve problems about structure, mechanism, and synthesis in organic chemistry. Because students often feel overwhelmed by synthesis problems, the training course helps the peer leaders model the problem-solving process for their students. We start by reading about problem solving *(30)*. In the training course, the discussion explores the differences between expert and novice problem solvers, the use of heuristics, and unstructured and structured approaches to problem solving such as Polya's *(36)* four stages (understanding a problem, developing a plan, implementing the plan, and evaluating progress). The peer leaders discuss their role in supporting the students to become more sophisticated problem solvers and apply the ideas to solving organic chemistry synthesis problems in the context of the starburst problem *(35)* (Figure 2).

Students are typically overwhelmed by the scope of the starburst problem and unsure of how or where to begin. The peer leaders reflect on how they approach the problem and break it down into generalized tactics in light of Polya's problem-solving scheme. To understand the problem, their tactics focus on comparing the reactant species to the product species: (i) count the number of carbon atoms in the chain, (ii) identify the functional group changes, (iii) determine whether a redox reaction has occurred, and (iv) evaluate regiochemical and stereochemical issues. Each observation holds implications for the development of the problem-solving plan, that is, identifying a set of reactions to cause the set of changes. Once a plan is developed and students start to arrange the reactions in proper sequence, the peer leaders introduce additional problem-solving skills such as working forwards and backwards (retrosynthesis). The evaluation stage involves considering alternative pathways, reflecting on the efficiency of the proposed synthetic route(s), and consider-

See how many synthetic connections you can make on the chart below. Start with acetylene (ethyne) and any other compounds containing three carbons or less and show how to synthesize the following compounds. Specify necessary reagents, conditions, and catalysts. In general, more than one synthetic step will be required. It will help to think "forward and backward" *(35)*.

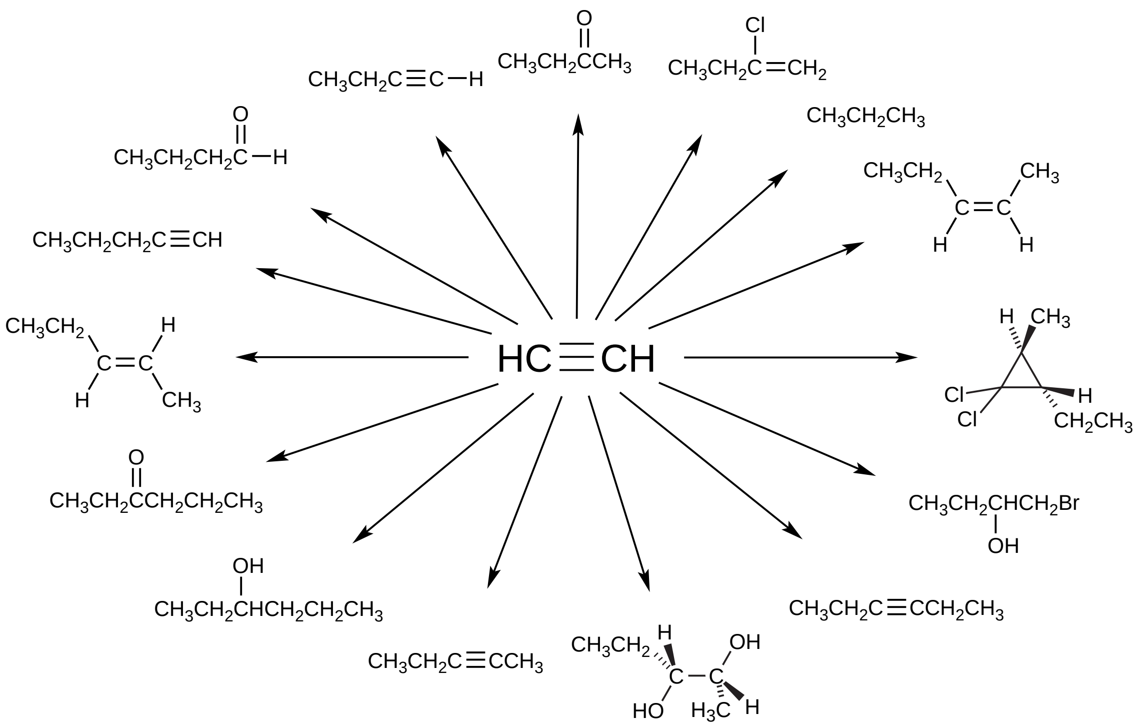

Figure 2. Starburst problem.

ing the possibility of competing reactions. The peer leaders play a key role in demystifying synthesis problems by guiding the students through the logic of problem-solving tactics. As such, the problem-solving unit of the course reiterates lessons learned from cognitive apprenticeship earlier in the semester. The peer leaders work to make visible the thinking processes underlying the construction of synthetic paths.

Results

This is, first, a set of observations that convince us that the peer leaders learned from the training course. The course has prepared both undergraduate and graduate student leaders for their new role as Workshop facilitators by helping them build rich conceptual and experiential CK and PCK bases. We see evidence of that in the successful implementation of the model. In 1995, students in the organic chemistry course were asked to evaluate their recitation or PLTL Workshop experience *(7)*. (These students experienced the same lecturer, textbook, recitation or Workshop problems, and exams; some students were in a recitation, while others were in a Workshop.) Both groups reported that the recitation or Workshop problems and the recitation teaching assistant or Workshop peer leader increased their understanding. However, the survey did reveal significant differences regarding the practices of the recitation teaching assistants versus the Workshop peer leaders; specifically, the students in the Workshop reported that interacting with other students and explaining their reasoning to one another had a much greater effect on their understanding than did the recitation students. This survey provides clear evidence that the training course provides an essential mechanism and the requisite support for introducing a new pedagogical model.

The peer leaders serve as role models for their students who want to become peer leaders; the leaders also recruit other students to become peer leaders. In addition, the leaders have been a driving force for the propagation of the PLTL model to other courses and other departments at our university. Faculty and educational specialists helped the dissemination process, but the peer leaders lobbied their teachers in other courses. Currently, the PLTL Workshop is being implemented in chemistry, biology, biochemistry, calculus, computer science, electrical engineering, and physics. Outside of the institution, our peer leaders have interacted and networked with leaders from across the country at national, regional, and project meetings. Peer leaders regularly represent

PLTL in workshops for faculty and leaders who are new to the model.

The impact of the training is also evident through the language and ideas expressed in the peer leaders' reflective journals, end-of semester comments, and written assignments. The journals serve as a sounding board for peer leaders to reflect upon application of the CK and PCK ideas. Representative comments from the undergraduate peer leaders are shown in List 1. In addition, interviews conducted with peer leaders at the end of the semester indicate that leaders internalize and implement both CK and PCK ideas *(7).* The final class assignment asks the leaders to report three principles that most influenced their leadership practice. While all of the reported principles are consistent with ideas presented throughout the training course, the top two principles were: (i) learning occurs best through apprenticeships and (ii) motivation is central to learning. In addition, peer leaders complete a research project as one component of the course. Leaders are free to choose any educational topic of interest and explore its relevance and application to the Workshop setting; however, many select topics that take them into a deeper study of CK and PCK issues introduced in the train-

List 1. Representative Peer Leader Comments from Reflective Journals and Written Assignments

Motivation

The most important aspect leading a workshop, in my opinion, is conveying one's enthusiasm about not the subject matter, but the process of learning for the sake of learning—exposing an intrinsic motivation…The greatest thing a teacher can do is instilling a passion for the subject in a student, which in turn triggers that inner motivation to learn. Though I can't claim to be a "passion-instiller", I've found that it is effective to show a personal appreciation for the subject that is not attached to any social connotations. For a certain type of student who is a "closet orgo [organic chemistry] lover" a typical exchange may start with me asking if they like the class so far. They usually claim that it's "ok" or something neutral. The moment I share a reason why I enjoy it, it can release a flood of comments about why they do as well. Though this doesn't necessarily make them understand anything better, but it demonstrates that there are those who are reasonably normal and enjoy the subject for the sake of knowing it.

Motivation is central to learning…If the students don't care about the material and aren't interested in learning the material, they won't be successful, and they won't get as much out of the course as they otherwise could…Having a leader who has gotten through the course and has chosen to come back to be a workshop leader is really beneficial, too. If not motivation to become a leader themselves, it shows that the course can't be all bad if people actually choose to come back to it.

Cognitive Apprenticeship

Last week, I basically talked them through the entire problem since they had never seen an O–D [Observation–Deduction] problem before—modeling. By modeling the problem, I provided a basic scaffold for the way to approach the problem (what observations are, what the first observation should be, what to do if they are stuck, etc.)…Throughout all of this, I would say that I was coaching them, providing them with the direction that's necessary to solve the problem. I used the "fade" part of cognitive apprenticeship for [the second problem]. This problem was a bit trickier and so I split them into two groups to get everyone to participate. As I watched from the other side of the room, I could understand that they had a firm scaffold of the observation–deduction problem; it was the chemistry where their scaffold wasn't very strong. Therefore, despite being in "fade" mode, I felt it necessary to introduce the coaching aspect as well, leading them with questions when they were getting stuck…Since it seemed to work well with the students and I got no opposition against what we did, I think I'm going to continue to use the cognitive apprenticeship model in most of my workshops.

I think that a large part of excelling at orgo is simply having confidence in your abilities and not second-guessing yourself. The moment I see fear in my students' eyes, I do what I can to help them understand that they can do the problem. A good way to curb this anxiety before it hits is to walk them through the first problem, so they can visually see the format and procedure for solving it. From this base point, they can then mimic and/or develop their own methods of solving the same problems. Many times, if I know that a new type of problem is headed their way, I will take a minute to walk through a similar problem, then I let them try the next on their own, offering hints along the way. Finally when they are good at them, I give no hints unless they are really stuck…Scaffolding is important for learning the process of problems solving in orgo, but also important for building confidence in their abilities.

Problem Solving

When the students first saw the Starburst they seemed frightened of the "large scary spider web."…I told them some little things they should keep in mind while attacking a synthesis problem. For example, I told them to first compare the reactant and product to see what is similar and different between the two. Next, they should ask themselves "Where is the most likely reactive site of the reactant that will yield the appropriate product?" It seems that they started thinking about the problem in little chunks.

I personally find [Starburst problems] easier to approach if I think about the three major aspects in a reaction (C–C additions? Functional group changes? Redox?) By knowing I have to examine such features of a reaction, I am able to work through a problem in an effective manner by knowing what must be done and how I will approach a solution. My students have seen the advantages of this firsthand. In the beginning of the semester, students approached one problem by just going at it and trying many different combinations of C's, H's, and O's. Unsuccessful, I had the students think about a plan of how they would approach the problem. When they realized what the question was asking and how they could systematically approach it, the students were able to solve the problem quickly, utilizing concepts and cognitive thinking, not just luck.

ing course. Some of the students' projects have been so pertinent that we have cycled them back in subsequent iterations of the training course.

We have also observed developing partnerships among the participants in the training class: peer leader–education specialist, peer leader–faculty, peer leader–peer leader, and education specialist–faculty. Just as the PLTL Workshop nurtures a collegial environment for the students and peer leader, the training course develops new relationships among the peer leaders and course instructors. The peer leader–education specialist and peer leader–faculty relationships are dramatically different from typical classroom interactions and start to resemble the reciprocal interactions and mutual respect that characterize a good research team. The peer leaders become a supportive community of learners as they debrief and discuss their classroom experiences with one another. These discussions validate their experiences and their reflections, build confidence, and enable them to take some control of their own development.

The training course experience also benefits the participating faculty and the education specialist. The training course is a structured mechanism for the peer leaders to provide ongoing feedback to the instructor regarding the chemistry course, the Workshop materials, and student difficulties. More fundamentally, it opens the door to new approaches to teaching and learning, introduces faculty to the educational research literature, and provides a mechanism to help faculty make the shift from a teacher-centered to a student-centered model of instruction. These new ideas can change a teacher's prior conceptions about teaching and learning, classroom management, and design of suitable materials and examinations. The education specialist benefits from the interplay between abstract theory and specific practice. Most importantly, the collaborative approach to teaching the peer leaders brings the education specialists out of the university's structured resources (e.g., Academic Support Services, Centers for Teaching and Learning) and into the classroom with students and faculty.

While the rewards of the training benefit all of the participants on multiple levels, there are also costs to implementing such a program. First, the training course requires an investment of time for everyone. Since many faculty have weekly meetings with their teaching assistants, the training course is not always a new time requirement. Additional preparation time for the instructors is necessary to assemble appropriate materials, identify relevant CK and PCK issues and give careful thought to their application to the training activities and the content of the science course, and to grade assignments and review the weekly journals. On the other hand, careful investment in preparing the peer leaders may lead to compensating benefits. When students have a support structure that meets their needs, they are less demanding of instructor's time and energy. Frustration levels decrease and the course becomes a cooperative effort to learn the subject.

A related set of costs includes identifying and compensating an education specialist and developing the partnership between the course instructor and education specialist. However, there may already be resources within the department or the university for training teaching assistants or tutors that can be tapped to support this training model. The important step is to identify and nourish the complementary roles of education specialists and classroom instructors. Some faculty may not recognize the value of leader training or may protest that they have little interest in pedagogical issues. Others may not see any benefits to their own professional development or career advancement and believe that time invested in educational pursuits will take up time that could be more productively invested in research. Even so, most faculty would be interested in a model that would make their teaching experience better or translate into greater success for their students.

Discussion

Our model of training peer leaders achieves two objectives: (i) preparation of novice instructors and (ii) curricular change. Since our training course has successfully prepared graduate students and postdoctoral fellows, we believe this course provides a general model to prepare graduate student teaching assistants. If teaching assistants are convinced of the productivity and viability of a new pedagogy *and* are effectively trained for their role, they contribute to and ensure the pedagogy's successful implementation. On the other hand, if teaching assistants are thrown into situations for which they are unprepared, they will likely revert to the teacher-centered instructional models that they know best *(37)*.

Many teaching assistant training programs are presented by the instructional services or faculty development unit of the university. These programs are often offered as crash courses before the term starts. Consequently, they are disconnected from specific classroom experiences and course content. At best, the teaching assistants may learn generic tactics for conducting recitations or laboratory sessions. Because of the lack of specificity to the course content, the instruction usually focuses on classroom knowledge with an emphasis on psychosocial dynamics and is ill suited to the presentation of pedagogical content knowledge and alternative instructional models. The inevitable result is the perpetuation of teacher-centered instructional modes.

Some departments try to address these deficiencies by offering departmental training programs. This gives legitimacy to the program because it is offered by the department. Even better, most faculty have weekly meetings with their own course assistants. However, these sessions usually focus on course operations and specific course content. These traditional weekly teaching assistant meetings are apparently not sufficient to counteract the assistants' prior enculturation into teacher-centered instruction. Recent reports document that these meetings failed to equip the assistants to work in nontraditional modes and, accordingly, failed to ensure teaching assistant buy-in *(38–40)*. According to Lewis *(41)*, "Teaching assistants need support, both on the fundamental concepts being taught as well as an understanding of why and how the new methods are being used." Our peer leaders understand why and how PLTL is implemented and are prepared to provide the cognitive modeling to make PLTL work; they are spokespersons for the PLTL model of learning.

Just as faculty prepare undergraduates to become researchers, the training course provides an infrastructure to start undergraduate and graduate students on the path to academic careers.[5] Coppola argues the need to develop programs to identify and educate teacher scholars, parallel to the structure that we use to identify and educate research scholars *(42)*: “Opportunities must be created that extend this [teaching] potential into independent experiences, to document and present the results from these activities, and to contribute to the professional culture of scholarly teaching to the same degree that undergraduate research contributes to its own culture” *(43)*. The leader training course validates the human desire to teach others and confers legitimacy to the scholarship of teaching and learning by its basis in the research literature. Simultaneously, the PLTL Workshop provides a valuable accompanying practicum. Together, they provide opportunities for undergraduate and graduate students to learn and to test interest and aptitude for teaching and to contribute to the development and application of a new pedagogy.

For some, the Workshop leadership experience is highly influential in their decision to pursue an academic career *(44)*. One undergraduate peer leader, for example, served as a teaching assistant for a traditional recitation in a general chemistry course prior to being a Workshop leader and said that leading Workshop “clinched it” for him to pursue a career that merged his interests in teaching and research. Another undergraduate peer leader identified her Workshop leadership experiences as being the single most important factor in deciding to pursue an academic career. Prior to being a peer leader, she was geared towards a research career in industry; however, she realized she enjoyed teaching, and her leadership experiences developed her communication skills and built her confidence in her teaching ability. Graduate students now apply to be Workshop leaders so that they can learn the ideas and the methodology; some enroll in the leader training course for credit so that their transcripts reflect this pedagogical experience.

Conclusion

The training course at our institution is designed to prepare students to become effective facilitators of team learning and group problem-solving activities. One key to developing competence is “to recognize how generalized strategies and localized knowledge interact” *(13)*. Consequently, the training course highlights ideas from educational research regarding teaching and learning and contextualizes those ideas to prepare the peer leaders to successfully implement an alternative pedagogical model, the PLTL Workshop. In contrast to training programs that discuss educational issues on an abstract generic level, this training program provides ongoing, “just-in-time” instruction to prepare the peer leaders for the upcoming week’s activities.

“Good teachers” possess extensive CK and PCK bases that have developed over the long term. To learn to teach effectively in the short term, novice instructors need to learn about CK and PCK from the research literature. The need for instruction is general, but acquires special urgency when curricular change is at stake. Based on our successful experience, we believe that our approach to preparing the peer leaders to facilitate the PLTL Workshop is a general model for teaching assistant training for both traditional and nontraditional roles. In addition to the immediate practical consequences, the course leads to new working relationships among students, faculty, and educational specialists. As a result, the course introduces current faculty to a new research literature in the short run, and it becomes a mechanism to encourage and enrich the development of the faculty of the future for the long run.

Acknowledgments

The authors thank their colleagues in the national PLTL project and particularly Ellen Goldstein, for her contributions to the development of the leader training model. This work was supported by NSF/DUE awards, 9450627 and 9455920.

Notes

1. A referee suggested that PCK can refer to pedagogical chemical knowledge in our course.

2. We have successfully used this training course model in other science courses. For a description of peer leader training for a biochemistry course, see Platt, T.; Barber, E.; Yoshinaka, A.; Roth, V. *Bioch. Molec. Biol. Educ*. **2003,** *31,* 132–136.

3. For a description of a M.S. program for the professional development of high school chemistry teachers that integrates pedagogy and content, see Bretz, S. L. *J. Chem. Educ*. **2002,** *79,* 1307–1309.

4. Recent studies in this *Journal* suggest that laboratory teaching assistants need explicit training about students and how they learn and about teaching and teaching methods. See (a) Herrington, D. G.; Nakhleh, M. B. *J. Chem. Educ*. **2003,** *80,* 1197–1205; and (b) Roehrig, G. H.; Luft, J. A.; Kurdziel, J. P.; Turner, J. A. *J. Chem. Educ*. **2003,** *80,* 1206–1210.

5. Some of these ideas have been previously presented at conferences. See these two examples: Roth, V.; Goldstein, E. *Peer-Led Team Learning: A Model That Prepares Group Leaders for the Present and Faculty for the Future;* Institute for Teaching and Learning: York University, York, England, 2001; Learner-Centered Universities for the New Millennium, 25th International Conference on Improving University Learning and Teaching, Frankfurt, Germany, 2000.

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