In this study, we describe a Performance Enhanced Interactive Learning (PEIL) workshop model as a supplement for organic chemistry instruction. This workshop model differs from many others in that it includes public presentations by students and other whole-class-discussion components that have not been thoroughly investigated in the organic chemistry classroom. Preliminary results based on the Colorado Learning Attitudes about Science Survey indicate that a PEIL workshop model not only influences student beliefs about chemistry in a positive way, but also enhances their academic performance. Assessment scores suggest that previous exposure to a PEIL model in Organic Chemistry I improved students’ performance in a subsequent Organic Chemistry II course. The positive influence of the PEIL workshop model in Organic Chemistry II on long-term learning gains is also demonstrated using student grades in subsequent biochemistry courses for which Organic Chemistry II is a prerequisite.

Organic chemistry is considered a “gatekeeper” course that students must complete before progressing toward advanced degrees or their chosen careers in fields such as chemistry, biochemistry, medicine, veterinary medicine, dentistry, or pharmacy. The subject demands a high level of abstract and analytical thinking as well as the visualization of spatial and electronic relationships in three dimensions. To a greater degree than in most other undergraduate science courses, organic chemistry is also inherently cumulative. Organic chemistry concepts cannot be neatly divided into discrete topics in the same way as they might in an undergraduate physics class, where subjects such as optics and magnetism share little conceptual overlap. Instead, fundamental ideas about spatial orientation, delocalization of charge, and electron flow are equally significant to all areas of organic chemistry, and students must continually reinforce these concepts in order to think about the subject in an expert way (Taagepera and Noori 2000). Consequently, those unaccustomed to this level and type of thinking often embark on an organic chemistry course with the mindset that it will be extremely difficult in comparison to other undergraduate classes (Carpenter and McMillan 2003).

Historically, many students have passed organic chemistry examinations using rote memorization of materials, often with minimal comprehension (Katz 1996). This strategy is characteristic of surface versus deep learning, and although it may be sufficient for retaining enough information over short periods in order to pass an examination, it does little to foster long-term retention of information or to allow transfer of knowledge within and across disciplines. Depth of learning is promoted when students are encouraged to explore concepts extensively and when emphasis is placed on critical analysis, the application of basic principles to novel situations, and active construction of knowledge through making new associations between concepts (Biggs 1987, 1993). A solid grasp of information and fluidity with concepts are probably markers of deep learning for many disciplines. However, because of the hierarchical structure of organic chemistry, it is particularly crucial to have a strong facility with its underlying fundamental principles.

One strategy that has proven effective in increasing the depth of student learning and retention of concepts involves the use of group learning workshops. Small-group learning
activities have been shown to have positive effects on student performance, persistence, and attitudes in college-level science courses (Bowen 2000; Springer, Stanne, and Donovan 1999). The amount of time spent participating in group learning activities is significantly correlated with their efficacy (Lewis and Lewis 2005). However, theoretical interpretations vary about why these methods work. Many emphasize the importance of social constructivist approaches to learning (Eberlein et al. 2008). For example, some very structured cooperative learning models such as Process Oriented Guided Inquiry Learning (POGIL) place great emphasis on defining the specific roles students play during the small-group interaction. Students are encouraged to practice these roles as they participate in the group’s social structure. Peer-Led Team Learning (PLTL) also places considerable importance on the social interactions that occur during small-group exercises, as students from different backgrounds contribute different perspectives and an active learning environment is created.

In contrast, other large-scale studies suggest that collaborative learning improves students’ problem-solving ability merely by having them articulate metacognitive problem-solving strategies to others (Cooper et al. 2008). PLTL has been shown to have a significant positive impact on the depth of learning and attitudes of organic chemistry students and their peer leaders (Tien, Roth, and Kampmeier 2002) as well as on student understanding and retention (Lyle and Robinson 2003). The Performance Enhanced Interactive Learning (PEIL) workshop model described herein involves facets of both POGIL and PLTL. As in the POGIL model, the instructor also serves as a facilitator during part of the PEIL activity. However, POGIL workshops were designed to replace lectures, whereas PEIL supplements the lecture series. PEIL also incorporates peer-facilitated, small-group discussions, which are a feature of PLTL. However, the PEIL workshop model differs from either of these other group learning strategies in that it also incorporates public presentation and large-group interaction components that have not been thoroughly investigated in organic chemistry classes. This paper presents a detailed description of the PEIL workshop model and a preliminary study of its effectiveness as a supplement to organic chemistry lectures.

**The PEIL workshop model**

“Performance” in the name Performance Enhanced Interactive Learning refers to the acting out or creative imitation by students of the language and culture associated with a subject, in this case organic chemistry, as they develop as learners of that subject (Holzma 2009). Based on Holzman’s interpretation of education settings, the PEIL workshop can be seen as a zone of proximal development in which organic chemistry students can try out their new language and its associated symbolism in ways that might be just beyond their reach if working alone. Students exchange roles with their instructor and play the part of organic chemists, experimenting with these concepts in front of an audience.

The weekly two-hour PEIL workshop session revolves around a set of problems relevant to the textbook chapter or topic covered in lectures during that week. The two accompanying 110-minute lectures per week, which include recitation time for answering students’ questions, provide a mechanistic scaffold of the knowledge necessary for students to arrive at their solutions by emphasizing the underlying concepts such as spatial orientation, delocalization of charge, and electron flow. However, the workshop questions are of a relatively high degree of difficulty, which encourages or even necessitates group discussion among students in trying to solve them. Attendance at these workshops is optional, so there is no credit or graded assignment associated with them. However, students in a class with a PEIL workshop cannot register for other classes during the workshop time, ensuring that all students can attend if they wish. No additional lecture material is covered during the workshop sessions, and all students have access to the workshop questions, even if they choose not to attend.

Each PEIL workshop session consists of three phases: small-group discussions, public presentations, and whole-class discussions. These three phases allow students to engage in different levels of performance related to the subject, some more improvisational than others. Students self-select their own workshop groups, but, once established, most groups tend to remain relatively stable throughout the semester. Before the small-group-discussion phase of the workshop begins, each group is randomly assigned a question to present later. However, all groups are expected to work through the entire problem set and contribute to the discussion pertaining to each question. The PEIL model, as practiced so far, is deliberately different from other models that place a very heavy emphasis on structuring workshop groups according to student ability or the roles that they perform. Also, although all students are encouraged to present the problem set at some point during the semester, no student is ever forced to do so. In allowing this degree of freedom, there is always...
the chance that some groups will not represent all levels of thinkers or that some students may not participate actively in the public presentation components of the exercise. However, these PEIL workshops were designed with the belief that such a degree of freedom will encourage students to feel greater agency in relation to their own learning, which could also have a significant impact on their performance. Personal observation of PEIL students supports this: The ability to structure their own learning experience within the workshops significantly contributes to their agency as learners and also generates a more positive psychological attitude toward organic chemistry. Anecdotally, PEIL students often report that they feel less motivated to participate when workshops are more structured in terms of groups and roles. It is hoped that future studies using a sociocultural–theoretical lens to examine interactions within the PEIL workshops will further elucidate some of these factors.

While groups of currently enrolled students attempt to solve the workshop problems, more senior students (who already completed the course with PEIL workshops during a previous semester) circulate among the groups. These workshop leaders are instructed to offer gentle guidance without actually providing students with answers to the assigned questions. After discussing the questions within their small groups, all students reconvene in a large classroom or lecture hall, along with the instructor and workshop leaders. This provides the venue for the next phases of the PEIL activity, where representatives from each group present their solutions and whole-class discussions of the results ensue. Emphasis on these whole-class activities is what distinguishes PEIL workshops from other group learning models. Typically, eight or nine problems are solved during each workshop session, and group members write their solutions to the assigned problems on the chalkboard. Once all of the solutions have been transcribed, presenters from individual groups describe their problem-solving process to the entire class. It is the responsibility of each group to decide which student (or students) will present their response to their question. Once a solution is given, it is open to critique by other students in the audience. Whenever there is disagreement about the presented response, alternative answers can be proposed and a debate will usually ensue until consensus is reached. Although the instructor facilitates this process, it is important that sufficient wait time is given for students to complete this argument on their own (Tobin 1987).

Patterns are deliberately established within the workshop setting that encourage students to determine for themselves when they are satisfied with answers given. For example, whenever an answer is presented, the instructor will ask students in the audience what they think and feel about the response, instead of making a declaration about whether it is right or wrong. Also, if a student asks the instructor a question related to what has been presented, the instructor will redirect the question and focus toward the presenter(s). Intervention by the instructor only occurs as a last resort or if a particularly effective opportunity for clarification or summation of ideas presents itself. In this way, the PEIL workshops provide a variety of opportunities for meaning to be refined and reinforced by students’ group members, other classmates, and workshop leaders. As the student presenters and those in the audience adjust to their new roles, they become better at improvising responses to the questions that arise during the workshop.

In order to evaluate the efficacy of the PEIL model, we attempted to answer the following two research questions: (1) Does a PEIL workshop model change student attitudes toward organic chemistry or toward science in general? (2) Does a PEIL workshop model promote deep learning, which is reflected in both relatively short-term and long-term academic success?

**Methods—Study 1**

The PEIL workshop class is popular among students. Nevertheless, many students enter the class with the preconceived notion that organic chemistry is very difficult. This lack of confidence could negatively impact academic performance. Perkins et al. (2004) have shown that greater retention and higher conceptual learning gains are exhibited by students who enter a course with more favorable beliefs, and that these beliefs can be influenced by the teaching practices they encounter. In order to investigate to what extent Organic Chemistry II students’ beliefs benefit from previous experience with a PEIL-workshop-based Organic Chemistry I class, we administered the Colorado Learning Attitudes about Science Survey (CLASS) to students registered in one section of the Organic Chemistry II course.

**Subjects**

Of a total of 73 students enrolled in an Organic Chemistry II class with an optional PEIL component at an urban, public university in New York City, 70 participated in this study. Informed consent was obtained from every student. Students were subdivided into two groups (PEIL and non-PEIL) on the basis of whether they had previously attended a PEIL-workshop-
based class for Organic Chemistry I (described previously). Because they register for Organic Chemistry I and II separately, 49 students (29 females) had completed the first half of the sequence in a PEIL-workshop-based course, whereas 21 students (11 females) had experienced a standard Organic Chemistry I course format with traditional lecture (2 × 110 minutes per week), which might include up to an hour of recitation per week in which the instructor answered questions posed by students about problems assigned from the textbook. Non-PEIL courses were taught by various instructors. All PEIL and non-PEIL classes cover the same topics using the same textbook. A similar number of exams are given in each type of class and have been judged by the chemistry department to be comparable in scope and quality. Eight of the non-PEIL students took Organic Chemistry I at another institution, but the remaining students simply elected to take a non-PEIL Organic Chemistry I class.

Attitude survey
In order to investigate to what extent Organic Chemistry II students’ beliefs benefit from previous experience with a PEIL-workshop-based Organic Chemistry I class, we administered the CLASS. Developed in Colorado and validated for both physics and chemistry, this survey is designed to gauge student beliefs about chemistry in general (Barbera et al. 2008). The CLASS asks students to rate 50 state-ments on a 5-point Likert scale and compare their responses to those of experts in the field. Responses to 45 of the items generate a general favorable versus unfavorable score, while 36 items probe specific types of attitudes from nine categories. These categories are personal interest, real-world connections, problem solving general, problem-solving confidence, problem-solving sophistication, sense making/effort (how important to you is it that you understand), conceptual connections, conceptual learning, and atomic-molecular perspective of chemistry.

Assessment of academic performance
Because the PEIL workshop model promotes cognitive processing that requires elaborative rehearsal of material, we assume that information will be deeply learned if students are active participants. Therefore, we hypothe-sized that exposure to a previous PEIL Organic Chemistry I course should give students an academic advantage in their Organic Chemistry II PEIL-based class. To evaluate relatively short-term learning outcomes, that is, performance in the Organic Chemistry II PEIL course, we compared assessment scores for students in the course who completed Organic Chemistry I using the PEIL workshop/lecture with the scores of students who completed their first semester in classes with the traditional lecture format. Assessments consisted of three midterm exams, each based on three chapters from the textbook, as well as a cumulative final exam. Additionally, students were required to give a 10- to 12-minute group presentation on a preapproved topic related to concepts learned in organic chemistry. Most presentation groups were the same as the workshop groups, and 50% of their score was from peer assessment. Students’ final course grade was computed from their two highest midterm exams, group presentation, and final exam.

Methods—Study 2
Because organic chemistry course material is consistently being re-trieved, manipulated, and re-encoded during the semester, the final grade in the Organic II course may not wholly reflect long-term retention of knowledge, because much of it has been in constant use. Empirical evidence suggests that when a period of study is over, forgetting occurs at a steep rate (Ebbinghaus 1913). Therefore, we also compared the performance in subsequent biochemistry courses of students who completed Organic Chemistry II using the PEIL workshop model with students who took a non-PEIL course. Although biochemistry courses do not often involve mechanistic interpretations of reactions in the same way that organic chemistry does, they do extend many principles learned in Organic Chemistry I and II to more complex systems. In comparing PEIL and non-PEIL students’ performance in this course, we hypothesized that if PEIL workshops result in students having greater facility with the fundamental principles of organic chemistry, this should be reflected in improved performance in this new discipline, as well.

Subjects
One hundred eighty-nine students enrolled in two different biochemistry courses (two sections of each) at the same institution as described in Study 1 were subdivided into two groups on the basis of whether they had previously attended a PEIL-based Organic Chemistry II class (PEIL, n = 60) or not (non-PEIL, n = 129). Twenty students in the non-PEIL group had taken Organic Chemistry II (and General Chemistry) at another institution; the remaining students had elected not to take a PEIL-based Organic Chemistry II course. All PEIL classes were taught by the same instructor.
**Academic performance**

Academic performance was based on the final grades for biochemistry and Organic Chemistry II courses. General Chemistry grades were also compared to ensure there were no substantial differences between the two groups prior to the workshop class.

**Results—Study 1**

The PEIL lecture/workshop model influences student attitudes toward organic chemistry and toward science in general. There were differences between the PEIL and non-PEIL groups in every CLASS category, with the PEIL group showing more positive attitudes or beliefs in each one (see Figure 1).

Although more favorable scores were obtained in all categories, they were only significantly different at the 5% level for the real-world connection category. However, statistically significant differences between the two groups for individual questions also provide insight regarding differences in beliefs between the two groups (see Tables 1 through 4).

**Results—Study 2**

By classifying students in subsequent biochemistry classes with respect to whether or not they had experienced a PEIL-based Organic Chemistry II course, we were able to evaluate the efficacy of the workshops on academic performance in a related discipline. As illustrated in Figure 3, these data confirm the benefits of the PEIL workshop model on the final grade in Organic Chemistry II. More long-term benefits were also apparent for biochemistry final grades. To confirm that these results were not due to inherent intellectual differences, we confirmed that the General Chemis-
try grades for the two groups were not significantly different, \( t(187) < 1 \). In order to maintain adequate power for comparison of Organic Chemistry and biochemistry grades, it was necessary to include students who took General Chemistry at a different institution. Consequently, General Chemistry scores were not available for 7 PEIL students and 24 non-PEIL students. Mean scores from the respective groups were substituted for missing data.

### Preliminary conclusions and future research

These results indicate that participation in PEIL-based workshops for organic chemistry produces benefits in terms of both student attitudes and academic performance. The PEIL students meet for an additional two hours per week over the time spent in organic chemistry by non-PEIL students. This means that PEIL students spend considerably more formal classroom time solving problems in chemistry than do non-PEIL students. However, in addition to this extended time on task, we also argue that the PEIL experience has many elements that promote deep learning and better conceptualization of organic chemistry principles.

One contributing factor is that students who register for PEIL-based classes are highly motivated. Because attendance at the PEIL workshop is optional (typically 80% of students attend) and students receive no academic credit, motivation is primarily driven by an intrinsic desire to attain facility with the concepts rather than to achieve a high “participation grade.” Intrinsic motivation is often a powerful aid to deep learning (e.g., Schiefele 1991). Second, the interactive nature of the workshops requires participants to articulate their thoughts. This is an

![FIGURE 2](image-url)

**Summary of performance for all assessments taken during the Organic Chemistry II course.**

These data reflect performance (mean and SEM) of 70 students from Figure 1, in addition to 3 more non-PEIL students who did not take the Colorado Learning Attitudes about Science Survey. Scores were statistically different between PEIL and non-PEIL students at \( p < .001 \) level for every assessment. PEIL = Performance Enhanced Interactive Learning.

![FIGURE 3](image-url)

**Mean GPA and standard errors for 189 students taking biochemistry classes after Organic Chemistry II PEIL or non-PEIL class.**

Although General Chemistry scores (pre-PEIL experience) were not significantly different between the two groups, scores for both Organic Chemistry II and biochemistry were significantly higher for the PEIL students. PEIL students (\( n = 60 \)) outperform non-PEIL students (\( n = 129 \)) by approximately one grade-point level (B+ compared with a B) in biochemistry classes, \( t(187) = 2.02, p < .045 \); and in Organic Chemistry II (B compared to B−), \( t(187) = 2.33, p = .02 \). PEIL = Performance Enhanced Interactive Learning.
important cognitive strategy, allowing tacit thoughts to be converted into explicit knowledge. Verbalization plays a vital role in memory consolidation and aids the formal organization of concepts. Efficient concept organization within semantic memory is key for successful long-term retrieval and cognitive flexibility in terms of understanding novel situations. Additionally, the formation and answering of complex questions encourages students to explore new ideas, allowing information to be conceptualized in a variety of ways that lead to more efficient memory encoding. Thus, we hypothesize that the workshop environment will be effective in creating greater fluidity and comprehension of the foundations of organic chemistry. Consequently, this will lead to better understanding of more complex materials and ultimately will be reflected in both short-term and long-term academic assessment scores. Although not explored in this current paper, many have theorized that the social interactions within collaborative learning workshops provide important foundations for learning.

We have demonstrated that prior exposure to a PEIL-based Organic Chemistry I program leads to better performance in a PEIL-based Organic Chemistry II course despite the fact that the workshop itself is ungraded. We argue that PEIL promotes knowledge to be consolidated more effectively and applied to new situations (and future classes) more successfully. Differences between previous PEIL and non-PEIL students were greatest at the beginning of the semester but still remained significantly different in the final course grade despite the fact that both had experienced a semester-long PEIL Organic Chemistry II class. This suggests that the benefits of the PEIL experience

### TABLE 1

**Students' attitudes to CLASS questions related to real-world applications of chemistry.**

<table>
<thead>
<tr>
<th>Question</th>
<th>CLASS categories</th>
<th>Non-PEIL % agree</th>
<th>PEIL % agree</th>
<th>Two-tailed t-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>36. Reasoning skills used to understand chemistry can be helpful to me in my everyday life.</td>
<td>• real-world connection • personal interest</td>
<td>58</td>
<td>92</td>
<td>t(68) = 3.38, p = .001</td>
</tr>
<tr>
<td>16. I study chemistry to learn knowledge that will be useful in my life outside of school.</td>
<td>• personal interest</td>
<td>42</td>
<td>71</td>
<td>t(68) = 2.29, p = .02</td>
</tr>
</tbody>
</table>

*Note.* The results for these questions are particularly interesting because, counterintuitively, the PEIL workshop problems do not involve real-world applications. However, more PEIL students believed they were able to relate chemistry to real-life situations than non-PEIL students. If students’ attitudes are an accurate reflection of reality, this would suggest that a PEIL experience may promote a deeper level of learning, because students appear to be applying their chemistry knowledge to novel situations outside of those experienced in the classroom or workshop. PEIL = Performance Enhanced Interactive Learning; CLASS = Colorado Learning Attitudes about Science Survey.

### TABLE 2

**Students' attitudes to CLASS questions related to problem-solving strategies in chemistry.**

<table>
<thead>
<tr>
<th>Question</th>
<th>CLASS categories</th>
<th>Non-PEIL % agree</th>
<th>PEIL % agree</th>
<th>Two-tailed t-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>49. When studying chemistry, I relate the important information to what I already know rather than just memorizing it the way it is presented.</td>
<td>• problem solving general • sense making (effort)</td>
<td>56</td>
<td>86</td>
<td>t(68) = 2.55, p = .01</td>
</tr>
<tr>
<td>25. If I want to apply a method used for solving one chemistry problem to another problem, the problems must involve very similar situations.</td>
<td>• problem-solving sophistication • conceptual learning</td>
<td>58</td>
<td>33</td>
<td>t(68) = 1.97, p = .05</td>
</tr>
</tbody>
</table>

*Note.* Large differences between the two groups of students were seen for conceptual learning, conceptual connections, problem-solving sophistication, and sense making (see Figure 1). These categories are aimed at evaluating whether students believe that chemistry is coherent and that they use reasoning and not memorization. Again, individual questions provide insight as to where attitudes of the PEIL and non-PEIL group are most discrepant. See also Table 3. PEIL = Performance Enhanced Interactive Learning; CLASS = Colorado Learning Attitudes about Science Survey.
are cumulative: Concepts that are well learned in Organic Chemistry I are used again in Organic Chemistry II. Furthermore, PEIL students may develop various skills that help them to identify how best to learn.

The analysis of academic performance in subsequent biochemistry classes also confirmed that students in these classes entered with higher Organic Chemistry II grades if they had attended a PEIL-based course than if they attended a more traditional lecture-based course. These data were not analyzed in terms of Organic Chemistry I experiences and so are reassuring in showing that attendance in a PEIL class at a later stage still has significant benefits. The degree of academic success in biochemistry was shown to be related to attendance in a previous Organic Chemistry II PEIL-workshop program. Again, this demonstrates the higher quality of learning that seems to occur in PEIL-based programs. Students are successfully applying their knowledge to new disciplines and are outperforming their peers who have not experienced the PEIL-model. Some of these benefits may derive from the fact that PEIL students are more likely to have better metacognitive skills and also may be more inclined

<table>
<thead>
<tr>
<th>Question</th>
<th>CLASS categories</th>
<th>Non-PEIL % disagree</th>
<th>PEIL % disagree</th>
<th>Two-tailed t-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>24. If I don’t remember a particular equation needed to solve a problem on an exam, there’s nothing much I can do (legally!) to come up with it.</td>
<td>• problem-solving sophistication • conceptual connections • conceptual learning</td>
<td>37</td>
<td>70</td>
<td>t(68) = 2.58, p = .01</td>
</tr>
<tr>
<td>21. Why chemicals react the way they do does not usually make sense to me; I just memorize what happens.</td>
<td>• problem solving general • conceptual learning • sense making (effort)</td>
<td>53</td>
<td>86</td>
<td>t(68) = 2.96, p = .004</td>
</tr>
</tbody>
</table>

Note. Significantly more PEIL students disagreed with these statements than non-PEIL students. Tables 2 and 3 indicate that, in general, more PEIL than non-PEIL students believed they were better able to “understand” concepts in organic chemistry and felt more successful and confident in applying what they knew. In contrast, more non-PEIL students believed they had a greater tendency to rely on memorization and less confidence in their ability to solve chemistry problems. PEIL = Performance Enhanced Interactive Learning; CLASS = Colorado Learning Attitudes about Science Survey.

<table>
<thead>
<tr>
<th>Question</th>
<th>CLASS categories</th>
<th>Non-PEIL % agree</th>
<th>PEIL % agree</th>
<th>Two-tailed t-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. I think about how the atoms are arranged in a molecule to help my understanding of its behavior in chemical reactions.</td>
<td>• Atomic-molecular perspective</td>
<td>68</td>
<td>90</td>
<td>t(68) = 2.20, p = .03</td>
</tr>
<tr>
<td>29. When I see a chemical formula, I try to picture how the atoms are arranged and connected.</td>
<td>• Atomic-molecular perspective</td>
<td>53</td>
<td>86</td>
<td>t(68) = 2.96, p = .004</td>
</tr>
<tr>
<td>44. Thinking about a molecule’s three-dimensional structure is important for learning chemistry.</td>
<td>• Atomic-molecular perspective</td>
<td>84</td>
<td>100</td>
<td>t(68) = 2.85, p = .006</td>
</tr>
</tbody>
</table>

Note. Related to the belief that they use more sophisticated conceptualization of organic chemistry concepts (as shown in Tables 2 and 3), more PEIL students than non-PEIL students also believe they are able to use an atomic/molecular, sophisticated conceptualization of molecular structure. Again, this demonstrates that more PEIL students believe they have a grasp of the more abstract three-dimensional conceptualization that provides the underlying framework for understanding chemical reactions. We hypothesize that this is a result of the PEIL workshop dynamic that encourages the development of a more sophisticated level of thinking through discussion with others who may possess a potentially broader knowledge base. PEIL = Performance Enhanced Interactive Learning; CLASS = Colorado Learning Attitudes about Science Survey.
to participate in study groups during subsequent courses.

One caveat to these data is that a greater percentage of Organic Chemistry I non-PEIL students (58%) had a break of more than one semester between Organic Chemistry I and Organic Chemistry II courses than those who had taken a PEIL-based course (10%). The majority of students had taken Organic Chemistry II at the same college, but eight of the non-PEIL group and one of the PEIL group had not. Because retention of information tends to decrease with time, this is a potential confound. However, PEIL and non-PEIL students in the biochemistry courses shared more similar timelines for their organic chemistry classes and differences in performance were still seen with regard to PEIL participation. This would seem to indicate that it is PEIL participation rather than recency of exposure that impacts academic performance. We anticipate that by collecting more data we will more effectively tease apart the effects of recency of exposure versus PEIL experience. We also plan to investigate PEIL-based workshops in Organic Chemistry I more thoroughly by examining the level of participation in such workshops impacts attitudes and learning.

Acknowledgment
Funding for this research was provided by the Responsive Research Network in Mathematics and Science Education in New York, New York (National Science Foundation Grant #412413).

References


Karen E.S. Phillips (kphil@hunter.cuny.edu) is an instructor in the Department of Chemistry and Director of the Pre-Health Programs at Hunter College of CUNY in New York, New York, and Jillian Grose-Fifer is an assistant professor in the Psychology Department of John Jay College of Criminal Justice in New York, New York.