Showing the True Face of Chemistry in a Service-Learning Outreach Course

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Boosting the public's perception of chemistry and increasing the number of qualified high school chemistry teachers have recently been proposed as goals for the discipline by the president of the American Chemical Society *(1).* College-level service-learning courses can promote both of these objectives at the same time. The service-learning process connects students with the community while simultaneously achieving learning goals *(2).* For example, students may conduct chemical analysis to assess water quality *(3),* participate in screening for lead paint *(4),* or develop chemistry projects or demonstrations for local elementary schools *(5, 6).* Many of these initiatives are in the context of a larger course, with the service-learning component often comprising some fraction of the laboratory curriculum.

Our institution has been highly supportive of service-learning initiatives, particularly following the recent establishment of a center for public affairs and civic engagement. Objectives of this center include expanding learning opportunities through closer ties to the local community. In the past, the Chemistry Department has participated in service learning through laboratory studies of local lake geochemistry *(7).*

In 2006, we developed a new service-learning course centered on chemical outreach that was offered during our four-week January term. Our goal for this course was for students to apply the chemical principles they had learned in prior courses in new settings and contexts to benefit the community. They achieved this by developing hands-on activities for children that illustrated the relevance of chemistry to society. We felt that this course complemented one of our institution's core educational precepts: "to explore in some detail one or more scientific disciplines, including experimental methods, and to examine the interconnections between developments in science and technology and the quality of human life" *(8).* Additionally, it allowed our department and our majors to participate further in our institutional civic-engagement initiative. Student course evaluations and surveys of the participating children suggest that our pilot course was a valuable experience for all parties and well worth the continued effort.

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Service-Learning Course Description

The prerequisite for this course was one semester of a laboratory-based chemistry course, either for majors or nonmajors. We limited enrollment to ten students. Although we anticipated that nonmajors with an interest in elementary school education might be very interested in this opportunity, nine of the ten students had in fact completed general chemistry, rather than a nonmajors course. More than half were science majors, and half were completing minors in education or planning a career that involved working with children (e.g., pediatric dentistry). Class standings ranged from first-year student to senior.

List 1. Example Chemistry Outreach Activities Created by College Students for Use with Grades 1–5 Elementary School Students

Activity Title	*Key Concept Taught through the Activity*
Glitter Wands	Density
Red, White, and Blue Liquid Layers	Density
Candy Chromatography	Mixtures
Super Strong Cereal	Atomic Nature of Matter
Cauldron Bubbles	Density; Chemical Reactions
Color Splash	Density; Miscibility
Witch's Potion	Chemical Reactions
Alka-Seltzer Rockets	Chemical Reactions
Which Dissolves Fastest?	Temperature and Reaction Rates
Bottle Balloon	Kinetic–Molecular Theory of Gases
Liquid Attraction	Density; Miscibility
Ooblick, Slime, and Polymer Balls	States of Matter
Invisible Ink	Acids and Bases; Chemical Reactions
Indicators	Acids and Bases; Chemical Reactions
Rocket Cars	Chemical Reactions

Because of the potentially wide range in background of the students, we designed the course with a lecture period to review key chemical principles and a laboratory period to develop outreach activities. The first two lecture meetings presented background material on the key concepts for science requirements at the elementary school level, including atomic theory, matter and energy, chemical reactions, and properties of solutions. During the first laboratory period, students themselves performed an age- and time-appropriate representative science activity *(9)* to gain firsthand experience of a successful model. Before the next laboratory meeting, each student submitted a proposal containing a minimum of two activities to investigate key concepts, plans to adapt these activities for different grade levels, and a list of needed materials.

Over the next week, students tested their own activities, presented them to the class for feedback, made refinements, and then peer-tested each activity. During this development stage, a 5th grader who was the child of one of the course instructors was an active participant and consultant. This aspect was particularly helpful to those students who had not had recent contact with children. The last phase of refinement was with children from a local after-school program who came to campus and worked with our students in small groups in our laboratory facilities. Small numbers of children and a controlled environment were critical to mentally preparing the college students for the off-campus classroom visits, as well as for suggesting necessary revisions to the activities they developed.

After the refinement stage, each student had one or two activities that could be easily adapted for children in grades 1 through 5 (List 1). Instructions and materials kits for teachers were finalized for these experiments. (Examples of these “teacher kits” can be found in the Supplemental Material.[W]) The course instructors had made prior arrangements for in-class visits with area teachers, including administration of a pre-visit survey to gauge the children’s attitudes towards science. During the third week, each student made at least two classroom visits to area schools, one as the team leader and one in a supporting role. Thus, there were two college students working with the children during each classroom visit. One of the course instructors was also present to observe and facilitate. Outreach teams spent approximately one hour in each classroom.

During the last week of the term, three 5th grade classes came to Colby to perform activities in our laboratory facilities. Again, each college student participated in at least two of these visits, taking either a lead or support role. After about an hour for experiments, children attended a chemistry magic show put on by the chemistry club and then went to lunch as guests in the dining hall.

Although the course was scheduled for four, two-hour morning lecture periods and two, three-hour afternoon laboratory periods per week, students were told at the start that they would need to be flexible with their time. Many of the classroom visits occurred during the morning period because of the elementary school day schedule, and one set of visits had to be rescheduled because of a snowstorm that caused public school cancellation. Conducting such a course during a January term (or May term at some other institutions) can be very beneficial to maximize student flexibility,

List 2. Course Components’ Grade Weights for Student Assessment

Coursework Components	*Contribution to Final Grade*
Laboratory notebook/journal	30%
Teacher kits	15%
Classroom visits	15%
5th grade visits	15%
Final presentation	15%
Peer assessment	10%

Assessment

Faculty Assessment of the College Students

We assessed several aspects of student work (List 2). Students kept a laboratory notebook that was graded weekly. This notebook included details about project development and personal reflections following each interactive session. Materials such as worksheets and handouts, which comprised the “teacher kits”, and student performance during outreach visits off-campus and on-campus were also graded. During the last day of the term, students gave multimedia presentations on their experiences, which were peer- and instructor-reviewed. All members of the Colby community were invited to these presentations.

Student Assessment of the College Course

Student evaluations of the course were extremely positive, with 90% of students strongly agreeing and 10% agreeing that the course was effective. Students commented that they learned not only from their experiments but also from the children with whom they worked. Specific representative comments included the following: “I learned things that I wouldn’t have learned in a normal classroom”, and “It was a great mix of science and education”. The only negative feedback was that one student felt that more work could have been required. We were somewhat cautious with our expectations for the first time through this course and may increase requirements in the future. Because of variability in the quality of the written material, we also plan to standardize teacher handouts by providing students with models from the first year’s class.

Effects of the Activities on Elementary School Students

In terms of impact on the community, children who participated were surveyed before and after the visits (Table 1). While we did not see any significant changes in the participants’ attitudes towards science after the outreach activities, attitudes were quite positive initially, leaving little room for improvement. For example, initial surveys revealed that 75% of the girls liked to read about science and 79% liked to study about science at school. Boys tended to be less enthusiastic

Table 1. Comparison of Positive Responses by Participants' Sex, Initially and Following Outreach Activities

	Survey Questions	Pre-Visit Positive[a] Responses		Post-Visit Positive[a] Responses	
		Boys, % (N = 100)	Girls, % (N = 81)	Boys, % (N = 94)	Girls, % (N = 79)
1.	Do you like to read about science?	66	75	57	71
2.	Do you like to do science experiments at home?	69	77	80	86
3.	Do you like to study about science at school?	61	79	68	73
4.	Do you like to watch TV shows and movies about science?	66	76	70	66
5.	Would you like to learn more about science?	81	86	80	92
6.	Do you want to be a scientist?	40	38	38	46
7.	Draw a picture of a scientist. (Values reflect children who drew a female scientist.)	4	65	5	65

[a]Positive responses are those in which students answered "yes" to a survey question.

Table 2. Comparison of Positive Responses to Question 6 by Participants' Grade and Sex, Initially and Following Outreach Activities

Question 6	Pre-Visit Positive[a] Responses, Grades 1–3		Post-Visit Positive[a] Responses, Grades 1–3		Pre-Visit Positive[a] Responses, Grade 5		Post-Visit Positive[a] Responses, Grade 5	
	Boys, % (N = 77)	Girls, % (N = 57)	Boys, % (N = 71)	Girls, % (N = 53)	Boys, % (N = 22)	Girls, % (N = 24)	Boys, % (N = 23)	Girls, % (N = 25)
Do you want to be a scientist?	45	51	42	57	23	8	26	24

[a]Positive responses are those in which students answered "yes" to a survey question.

but still responded quite favorably (66% and 61% for these questions, respectively). These positive attitudes may have arisen in part from their teachers, who were selected because of close ties to our department (e.g., the parent of a former chemistry major, the spouse of a visiting chemistry professor, and past and present teachers of course instructors' children). We did observe some encouraging trends in the data, such as increases in the number of girls who wanted to learn more about science and the number of children of both sexes who reported that they liked to do science experiments at home. However, these increases were not statistically significant. In order to facilitate our analysis, we will expand the range of choices on our survey in the future. Nonetheless, anecdotal evidence acquired by the instructors from later contact with some of the children suggested that they greatly enjoyed these visits and would like to do more of such activities.

Because we noticed a clear difference between 5th graders and the younger children in their responses to the question "Do you want to be a scientist?", we also analyzed these responses by age (Table 2). On the initial survey, about half of children in grades 1 through 3 reported that they wanted to be scientists, although less than 25% of boys and 10% of girls in grade 5 did. We suspect that younger children have less knowledge about science careers to answer this question. More science homework and the pressure of letter grades may also contribute to the decline in the 5th graders. However, positive responses to this question increased after the outreach activities for most groups, with the 5th grade girls showing the greatest gains.

The survey also asked each child to draw a picture of a scientist. Some of these portrayals emphasized a degree of scientific mystique, with the figures saying such phrases as, "I have the biggest brain ever", and "I was born ready". We used characteristics such as hair length, facial hair, and gender-identity labels (e.g., "Dr. Jan" and "Bill Nye the Science Guy") to assess the gender of the scientists. Although gender could not be identified for 18% of girls' drawings and 46% of boys' drawings, we noted that 33% of the total scientists (pre- and post-visit surveys) were clearly female, a dramatically larger percentage than the less than 1% noted in a previous study *(10)*. Indeed, one of the participating teachers observed in a school newsletter that she had "seen a difference in the way scientists are depicted in student drawing. Gone are the old men in lab coats, replaced by young women wearing safety glasses" *(11)*.

Possible reasons for the relatively high number of female scientists drawn include the higher visibility of women scientists in popular culture, an increase in the number of female health care professionals, and outreach trips made by female scientists into some of these schools in recent years. To minimize the latter effect, we did not survey one class because of extensive prior contact with one of the Colby female scientists whose daughter was in the class. Overall, a higher percentage of girls (65%) than boys (~5%) drew female scientists.

Feedback from participating elementary school teachers about the visits was also very positive. This representative example is from a 5th grade teacher who brought her class to Colby.

> My class was very excited about the whole day. They had lots of great ideas about why things happened in the activities you did today. It was a fun day that got their juices flowing. I was actually *very* impressed with their ability to work when we went back. We spent time thinking and talking about more science and they were really on!

Teachers who sponsored the in-classroom visits were equally enthusiastic, as demonstrated by the following comments from a 2nd grade teacher.

> The students were really excited about the science and many of them have continued to have an interest in science throughout the year…having the Colby students come made this a unique and memorable experience that increased the students' excitement level about science and showed my students that science can be fun…having the Colby students visit was beneficial to my students even beyond the science. It is good for many of the students to have exposure to college students because it shows them that college students are real people that they can emulate someday. Many of my students said afterwards, "I want to go to Colby and be a scientist. They get to wear really cool glasses and do fun experiments!" Even if their excitement stems from cool experiments and cool goggles, this is positive exposure to the collegiate world that they will remember. It makes Colby seem like less of a far off, scary, unrealistic place and goal.

Conclusions

With the recent increased emphasis on socially responsive knowledge across many disciplines, chemistry departments have a unique opportunity to develop new venues for their students to interact with the community. A formal, graded experience encourages students to take ownership of the design and implementation of the outreach activities much more than if they were simply helping out a faculty member in area classrooms. Moreover, the problem-solving and active-learning nature of service-learning courses complements conventional classroom learning. Key aspects of service learning include developing a foundation of knowledge that can be put into action to benefit society, thereby empowering both the students and the members of the community with whom they work *(12)*. Chemistry students can help combat the rising tide of scientific illiteracy by making chemistry approachable for elementary school children, thereby building the chemical confidence of both parties. Furthermore, service-learning courses allow us as practioners to share the excitement of our discipline with the college students of tomorrow, showing some of these children the true face of science for the first time.

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[W]Supplemental Material

Sample activity instructions for elementary school teachers and worksheets for elementary students (grades 1–5) are available in this issue of *JCE Online*.

Literature Cited

1. Carroll, William F. *Chem. Eng. News* **2005**, *83,* 2–4.
2. Wiegand, Deborah; Strait, Melissa. *J. Chem. Educ.* **2000**, *77,* 1538–1539.
3. Draper, Allison J. *J. Chem. Educ.* **2004**, *81,* 221–224.
4. Kesner, Laya; Eyring, Edward M. *J. Chem. Educ.* **1999**, *76,* 920–923.
5. Esson, Joan M.; Stevens-Truss, Regina; Thomas, Anne. *J. Chem. Educ.* **2005**, *82,* 1168–1173.
6. Hatcher-Skeers, Mary; Aragon, Ellen. *J. Chem. Educ.* **2002**, *79,* 462–464.
7. The Colby Compass. A Floating Lab for Lake Research. *http://www.colby.edu/chemistry/Colby%20Compass/Colby%20Compass.htm* (accessed Jul 2007).
8. The Colby Plan: Mission and Precepts. *http://www.colby.edu/academics_cs/catalogue/2005_2006/general_information/colby_plan.cfm* (accessed Jul 2007).
9. Wally, L. M.; Levinger, N. E.; Grainger, D. W. *J. Chem. Educ.* **2005**, *82,* 1489–1495.
10. Chambers, David Wade. *Sci. Educ.* **1983**, *67,* 255–265.
11. Juskewitch, Dawn. Giving Science a New Face. *The Fifty Niner* **2006**, *March,* 1.
12. Altman, Irwin. *Am. Psych.* **1996**, *51,* 371–378.