Perspectives from a Female Undergraduate Student on Successfully Integrating Learning and Researching Science with Leading Organic Chemistry Workshops

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Introduction

Although we realize that organic chemistry can be a major challenge and in some cases a stumbling block to students in achieving their career goals, [1] this subject also serves as a cornerstone to many scientific, technological, and medical advancements.[2] Conveying this message and teaching the subject matter in an interesting way, one that can be understood by both male and female sophomore organic chemistry students, is and has been a formidable challenge. Further, it is becoming increasingly clear that there exists a strong need to change the way science is taught in order to appeal to both male and female students. [3] Organic chemistry workshops offer students a novel approach to hone problem-solving strategies and develop effective communication skills in a non-intimidating atmosphere.[4] This approach offers new pedagogical techniques for reform of traditional teaching methods for a variety of related disciplines at diverse institutions (e.g., colleges, universities, and institutes of technology),[5] techniques that are potentially more "female-friendly,"[6]

attracting and retaining women in chemistry, yet also retain their appeal for male students.

Organic chemistry workshops are one-hour weekly sessions in which eight or fewer students, facilitated by a peer group leader, actively engage in the learning process. These workshops offer students with a variety of learning styles a novel approach to honing problem-solving skills in a non-intimidating atmosphere. Workshops are viewed by students as a safe haven in which to engage in a collaborative effort to solve problems. Students learn to develop problem-solving strategies not only from their peer leaders but also in collaboration with their colleagues.[7] We have observed that the supportive atmosphere, due in part to the peer leader, plays a major role in allaying the feelings of being overwhelmed often demonstrated and documented by the students. In addition, workshop leaders inspire, instill student confidence, and promote and encourage speaking the language of chemists to foster interactions with and between students. It is also a time in which peer leaders serve as role models and have the opportunity to convey an appreciation, understanding, and enthusiasm for the subject matter.

The focus of this essay is to introduce and elaborate innovative strategies and new approaches in three areas—learning, teaching, and researching in chemistry-related disciplines—from the perspectives of a female undergraduate student (that is, Nermana Ligata), a peer leader, and a researcher, respectively, with emphasis on peer-led workshops in organic chemistry. We hope that these insights will encourage faculty to adopt and adapt similar initiatives in undergraduate courses they teach (e.g., chemistry, physics, mathematics, biology, computer science, environmental science, engineering, and geology), to assist both genders[8] in mastering all three areas, and to effectively emphasize breaking the gender barrier in science and technology. As a result of this perspective, we anticipate that the curricula and teaching techniques described herein may initiate new approaches and/or extend existing ones and thus make science more attractive to women.

It is our intention that, by assisting them to succeed[9] in these three areas, workshop participants, regardless of gender, race,[10] religion, nationality, socioeconomic background, and so forth, will benefit from these insights. The ultimate goal is that the science community reflect the diversity of backgrounds found in the general population.

Discussion

Both learning and teaching science-related courses can be intimidating, especially for female students. We believe that self-discipline and taking an active role in being responsible for one's learning, together with peer support and guidance, are essential tools for mastering important concepts in science. This, in fact, is the philosophy of the workshops that are proving to be an invaluable resource for students taking science courses such as organic chemistry. These workshops provide an opportunity to acquire other methods for solving problems, through the use of "peer brainstorming" or "think tank" panel discussions.

The intent of organic chemistry workshops is to enhance learning chemical concepts, problem-solving techniques, and verbal communication skills. Through collaborative efforts, workshop students solve problems. Together with the peer leader, students share different approaches to problem-solving and discuss organic chemistry concepts[11] and topics as they relate to everyday life experiences. Workshop participants have indicated through verbal feedback that both listening to their peers give a variety of methods to solve a single problem and explaining solutions to problems have enriched their learning experience and increased their repertoire of problem-solving techniques and strategies. Furthermore, the diverse nature of workshop participants provides a means for disseminating insightful learning techniques and sharing a wealth of knowledge beyond that discussed in the classroom. Responses from both students and peer leaders to surveys conducted at American University (AU) have been positive; such positive responses also have been noted by previous investigators using the workshop model.[12]

Workshop leaders take great pride in watching their students' knowledge and enthusiasm expand. For example, when a student says excitedly "I really understand this concept now," both the student and workshop leader feel a true sense of accomplishment.[13] From Ligata's perspective as a student workshop peer-leader, workshops have also proved rewarding, reinforcing her own knowledge of organic chemistry while enlightening her about new problem-solving techniques. Weekly sessions also provide the time and place to share advice on studying for course and national entrance exams, life experiences, or scholarly research and academic accomplishments and to discuss possible occupational opportunities in chemistry-

related fields—including information on co-ops, internships, work experience, and career-related matters. Summer research opportunities with local private or government-funded companies like the National Institutes of Health (NIH), as well as contacts in the university career center and other resources, may be suggested by peer leaders. Modes of compensation, whether through salaries or university credit toward academic degrees, are also discussed. However, the important focus is to motivate and encourage those students who desire to pursue academic, laboratory vocations, and get firsthand experience conducting scientific research. An important factor to help students get in the door of a laboratory, especially for female students, is to believe in themselves as scientists. This can be achieved with self-confidence and competence, which we believe the workshop model encourages.

We are cognizant of the impact of gender issues on women and deeply committed to the application of academic scholarship by women.[14] Participants in workshops led by women have agreed with Claude Bristol[15] that women are naturally superb scientists because they are naturally analytical, have curiosity and observational powers, and have good communication skills. Female scientists who have made unique and significant discoveries and contributions to the field are discussed in workshops. Workshop leaders encourage students of both genders to recognize their abilities and to discuss the fact that women scientists continue to play a positive role in scientific and technological advancements. As a peer leader, Ligata found that these discussions about research and women in science helped validate her own personal experiences and reinforce the idea that women make good scientists, thus encouraging her own research pursuits as a female scientist.

It is important to mention that the physical sciences remain professional areas in which women still have not broken the gender barrier. A 1994 report from the National Research Council and references therein revealed that even though women constitute 45 percent of the labor force, only 16 percent are employed as scientists and engineers,[16] with 12 percent in industry[17] and an even lower percentage of women scientists and engineers in academics.[18] In addition, results of a 1991 study of 276 colleges and universities stimulated awareness that less than 40 of 400 recruitment and retention programs were aimed at female students or faculty in science or engineering.[19] Such statistics illuminate the facts that a gender barrier does

exist, with most scientists being male, and that learning, teaching, and researching in science may, indeed, reflect a masculine perspective.

As one would anticipate, female faculty and workshop leaders at AU have not been immune from experiencing gender bias, and some have had to conquer arduous obstacles in order to break through the glass ceiling in chemistry-related fields as students, teachers, and/or researchers. They readily share these experiences with their students. For example, as a workshop leader Ligata described for students her research experience at NIH and her enthusiasm for science, which escalated. She stressed that hands-on experience has many benefits and is a necessity for students interested in pursuing science-related careers. Such research experience provides a time in which students can put into practice and apply what they have learned. Students can gain firsthand insights through hands-on laboratory work, regardless of whether this is the career path they choose to pursue. These experiences also stress the importance of writing and communication skills for doing scientific research and being successful as a scientist.

After successfully completing the organic chemistry course, most peer leaders at AU pursue chemistry-related disciplines and successfully earn positions as scientific researchers in government, industry, and/or academic settings. Thus, peer leaders often share their excitement and research experiences with students during workshops. For example, leaders with research experience can address such student questions as, "How does one get hands-on experience as a scientist?" Responses vary greatly, but leaders stress that "It isn't necessarily whom you know but rather how you project yourself to the people you do know and the ones you meet." Other advice given is that "in science it is important to network since nearly every scientist's research involves collaborating with colleagues" and "an enthusiastic, articulate, and confident person is more likely to be asked to do an internship or get work experience than a nonchalant person, even though they know or have met the same person."

The workshop peer leader also helps students see science in its social context and connect what students learn to practical uses, everyday life experiences, and their environment. Thus students do not feel as detached from the material they are learning. This further helps to ameliorate the intimidation that students in science courses generally may feel. Students quickly learn that workshops involve group interaction and that everybody's input is a valuable contribution to everyone's overall learning.

Through workshops, we foster mutual respect and encourage students to listen to the way other students approach problems. For example, workshop participants believe that the workshop experience and curricula are invaluable and serve as vehicles for both learning and teaching the subject material.

Open communication also allows the students to share their fears and the learning blocks they experience with respect to learning organic chemistry. Their fears—usually feelings of being overwhelmed by the amount and nature of the material—are taken seriously. Through expressing these feelings that they may not be able to grasp it all, students are comforted to know that they all share similar fears, as did the workshop leader when he/she began his/her course of study. They are also comforted by the fact that each student's input during the workshops is part of a team effort in overcoming these fears. As workshop leaders, because we now understood what their fears are, we can find ways to respond to and eliminate them. Techniques such as visualization, tree diagrams, concept maps,[20] and so forth, are of great benefit in allaying these fears and addressing the learning of the subject matter. For example, tree diagrams and concept maps are initially constructed by the leader to demonstrate their format and utility. Next, each workshop student produces her or his own version. Such tools and other mnemonic devices have proved effective for both connecting the concepts and reactions and memory recall.

To avoid feeling overwhelmed by the sheer number of different reactions, reagents, and so forth, students are taught and encouraged to approach organic chemistry through effective organization of the material according to the fundamental similarities of reactions of individual functional groups and their mechanisms, rather than by compartmentalizing the information. Thus, from an understanding of the fundamental underlying principles of the properties of single atoms to the intricate complexities of intermolecular interactions of molecules containing a variety of functional groups, acquisition of a foundation of knowledge of organic chemistry becomes an exciting and thought-provoking subject.

Strategies and ideas discussed at workshops help visualize chemical concepts, which ultimately helps establish a solid foundation of knowledge. For example, describing a conceptual model of a group of negatively charged electrons as gray-colored dots flying in an octet formation around atoms represented by balls helps students see and feel the concept of res-

onance. Thus, students can gain an intuitive understanding using a visual approach that also enhances memory retention. Furthermore, as students' learning increases, higher-order thinking can lead to the understanding of more advanced chemical concepts.

Based on a working knowledge of the basic principles of organic chemistry, new concepts discussed in lecture are reinforced through practice by solving problems relevant to the newly introduced concept. Through workshop exercises and homework problems, problem-solving skills are enhanced. Students quickly learn that this approach is beneficial for a number of reasons, including the following:

1. A particular functional group found in many different compounds reacts similarly, so associations can be made.
2. Repeated problem solving allows for many of the reactions to become second nature. This builds confidence in learning abilities while simultaneously reducing the amount of time it takes to complete problems. This is particularly beneficial for making effective use of exam time, reducing the time required to complete the questions and therefore providing time to go back and check over the exam.
3. Working on the problems consistently and attending workshops has another advantage. By the time a student gets to the exam, it is like sitting down to do homework problems once more, which lessens the anxiety that exams can create. As a result of developing good test-taking strategies, a more relaxed atmosphere can be established, which then allows students to recall the material more quickly and easily. These efforts are rewarded with many benefits, including the reduction of time spent studying.

Overall, workshop experiences benefit both students and peer leaders in terms of success in learning, communicating, and applying chemical concepts. Additionally, workshop leaders' knowledge and confidence strengthen, which further benefits their research experiences and opportunities in science.

Conclusion

Participants of both genders find that the workshops are enriching, stimulating, and beneficial to their success in understanding and applying chem-

ical concepts. The workshop leaders also feel that they benefit, in terms of applying what they have learned and engaging in scientific research. As well, peer leaders can share their research experiences and techniques of using mental pictures, tree diagrams, and so forth, to assist students in understanding chemical concepts. The students find such stimuli and interactions not only beneficial to their understanding but enjoyable. Students can form their own mental pictures and share them with the rest of the group, applying cartoon images and personalities to compounds and reactions as a way to understand and recall structures, reaction types, and mechanisms.

The workshops also include discussions of a variety of current topics covering chemistry and science. In general, students who have participated in workshops feel more confident with their abilities in organic chemistry. Confidence and competence are built from knowledge that arises from persistence in learning, with the assurance that there are a variety of tools and resources available to use in the process. During the course of the semester, students' fears about the course subside. Fear comes from not knowing about something and leads to insecurities about personal abilities. Through group brainstorming and reducing the material to manageable segments, the students can overcome their fears. They also can apply similar approaches to other courses. For example, several organic chemistry students who concurrently were taking courses such as genetics and cell biology formed their own workshoplike sessions. The organic chemistry workshops have proved to be beneficial not only for learning course material but also as effective vehicles to instill confidence about one's abilities to succeed in science.

Notes

We are grateful to Dr. David Gosser at the City College of New York, Pratibna Varma-Nelson at St. Xavier University in Chicago, Jack Kampmeier at the University of Rochester in New York, and the project evaluator, Leo Gafney, who provided invaluable assistance and support to the chemistry workshop project at American University. Currently, the workshop project at San José City College is supported by the National Science Foundation DUE-CCD through collaborations with Mark Cracolice at the University of Montana-Missoula, Jim Reed at Clark and Atlanta University, and Joseph Wilson at University of Kentucky; the University of California Santa Cruz-Education Partnership Center program with

Lisa Hunter; the San José State University-Math and Science Teacher Education Program; and a San José City College Partnership for Excellence grant.

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