The Value of Hands-On Science Education

An Honors Thesis (Honors 499)

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May 2007

May 5, 2007
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Abstract

Recent journal articles have shown that some members of the scientific community are not convinced of the benefits of laboratory teaching in undergraduate non-major chemistry courses. These courses are often general education requirements for students at the college level. In response, many professors have written responses about the success found in the laboratory. In a laboratory setting, students develop skills that they can apply to other disciplines, as well as battle a problem among the general public termed "science illiteracy." In order to support this conclusion, I have reviewed many articles on the topic of laboratory teaching and the results are presented here. I have been convinced of the benefits of a laboratory section in undergraduate non-major coursework, hence, I have also presented some proposed experiments that could be added to the current CHEM 100 People and Chemistry course at Ball State University.

Acknowledgements

--- I would like to thank Dr. Jason Ribblett for advising me on this project and providing me with solid resources on which to begin my research.

--- I would also like to thank Erin Elward, Katie Hendrickson, and Ethan Miller for their inspiration and support throughout this process.
Laboratory Courses in Chemistry

Chemistry. The word itself calls to mind images of a scientist busy at work in the laboratory with boiling liquids in beakers and pages of data in a laboratory notebook. This idea of chemistry has been challenged recently. It has been the opinion of a few scientists that chemistry should not always be taught with a laboratory. This view is generally met with much opposition throughout the scientific community; there are many more scientists who are vocal about the benefits of a laboratory course than those who find the negatives in such a course. At Ball State University, CHEM 100 People and Chemistry, an undergraduate non-major course, does not employ the use of a laboratory section. By examining research about laboratory teaching, as well as the opinions of many successful professors around the country, it is obvious that laboratory can be used to improve the education of the students who take chemistry as a general education requirement. Laboratory also provides the opportunity to give students a positive view of chemistry, which could benefit the discipline in the future. Schools like Ball State University should add a laboratory to the chemistry courses that currently lack them in order to better educate students from other departments.

Stephen J. Hawkes, an emeritus member of the Department of Chemistry at Oregon State University, wrote a commentary for the Journal of Chemical Education entitled “Chemistry is Not a Laboratory Science” in which he expresses his doubts about the benefits of a laboratory course (3). Hawkes insists that the skills learned in undergraduate chemistry laboratory courses are not “useful enough to non-majors that they should be required to take a lab course, or that we should provide it in preference to the other teaching for which time and resources could be used.” Hawkes also comes to the conclusion that computer simulations could meet the same requirements. At a more basic level, Hawkes entertains the idea that chemistry is not a
laboratory science because it has existed long before there were laboratories, humans, or experiments. His conclusion is based on the presumptions that there is little proof of the benefits of laboratory and that chemistry is, at a basic level, not a laboratory science. He believes that resources, such as student interest, funding, and faculty time, should not be wasted on such endeavors.

Two successive letters from scientists affiliated with other universities were published in direct opposition to Hawkes’ ideas in the Journal of Chemical Education. In one reply, Chad E. Stephens from the Department of Chemistry at Georgia State University found that Hawkes’ argument presented one of the reasons to keep the laboratory course: “students learn valuable manipulative and visual-motor skills in the chemistry laboratory” (4). Many hands-on experiences will benefit these students. Stephens also believes that it is foolish to consider removing laboratory courses based on time or budget constraints. In his impassioned argument, Stephens writes that he finds “there is no better place to make chemistry come alive for our students than in the laboratory. And as student interest in chemistry continues to decline, we need to look for innovative ways to reverse this trend.”

Emeritus Lawrence J. Sacks of Christopher Newport University in Newport News, Virginia, also found some holes in Hawkes’ logic (5). To Hawkes assertion that chemistry existed before laboratories and is, hence, not a laboratory science, he writes that

“It implies that the ‘principles’ and ‘facts’ are properties as substantial as matter itself. How many examples of rejected ‘principles’ are needed to confirm that they are anthropomorphic creations, rather than inherent properties? And how many ‘facts’ have to be modified, restricted in scope, or even retracted before they, too, are recognized as human efforts? If it is argued that such rejected concepts weren’t really ‘principles’ or ‘facts’ (having been overthrown), then the argument requires that we have now reached the position of absolute knowledge of the physical world, in which case we should probably all go home and let the computers figure out everything” (5).
This response is slightly theatrical, but Sacks does insist upon full consideration of the benefits of laboratory when determining whether they should be kept in the curriculum. Although chemistry did exist in essence before society understood some of the finer workings of its principles, the importance of chemistry mainly comes from the discoveries that we have made in the laboratory. Appreciation of these discoveries and how they are made, as well as a demonstration of the principles that govern the everyday world of even non-science majors are strong reasons to keep laboratories in those undergraduate non-major courses.

Other chemists have written in support of Sacks and Stephens. In a letter to Science, a professor from the University of Maryland lamented, “I feel that the project or problem method produces the most favorable conditions or situations for arousing and holding the original tendency of curiosity... a project is a piece of work carried out in its natural setting. The laboratory is the natural setting in the study of chemistry” (12). A professor at the Case School of Science, in Cleveland, Ohio, also wrote in Science, “Concerning details of the most efficient methods in teaching general chemistry, no doubt an extended course of experimental lectures, closely connected with laboratory practice, affords the best training” (13). The same article cites that by stressing the importance of precision and accuracy in laboratory work, students can apply these qualities of analysis to their chosen fields. In a Review of Educational Research, several other scientists found that “the experience possible for students in the laboratory situation should be an integral part of any science” (15). They continued, “The laboratory provides a unique medium for teaching and learning in science education, and science educators have suggested that rich benefits in learning accrue from its use” (15). In fact, review after review shows that there are many scientists who feel the same way. These professors are using laboratory as a teaching method, noting the behavior of their students in the laboratory, and acknowledging that
it is an integral part of science education. Feedback from professors and students is the most reliable data we have, and it appears that most of them enjoy and benefit from the laboratory. Furthermore, it appears that for every professor who criticizes the laboratory course, there are four or five others who feel strongly about the benefits of a laboratory section.

Chemistry in Society

Another reason many scientists feel strongly about the need to educate non-science majors with positive, applicable, laboratory experiences is the widespread problem of science illiteracy (10). In the 21st century, scientists are designing medical treatments, instruments of warfare, and environmental breakthroughs based on higher level science. In order to find public support for these endeavors, the scientific community must have the trust of an understanding society. Creating an environment that is supportive of the sciences is more easily accomplished when the society understands the pros and cons of certain developments and the academics behind them. When the complete background of a new discovery is available, the public can make an informed decision about whether or not to support the science in question. For example, research involving stem cells has come under much scrutiny since major developments have been made in the field. There is a debate about whether the cells are coming from simply another bundle of cells or an actual baby; the boundary where life begins is in question. Using these cells is a question of ethics, and these issues are decided by politicians who enact laws for or against such research. If the politicians and their constituents understand the information that is presented to them, then they can make an informed decision that makes the best of both the benefits offered by science and the values of the society (6). It is unclear just when this science
illiteracy problem began, but many scientists feel that more people need to have a basic science background to understand major issues that will affect their lives in the 21st century.

Science literacy can include understanding why it is hotter in the summertime or that the Earth revolves around the Sun once a year---two concepts cited by a recent article as common gaps in the scientific knowledge of the general public (10). When talking about more complex discoveries, it would be asinine to expect politicians to understand the inner workings of cold fusion or cell culture techniques. In these cases, even basic science literacy can help the public to understand the information provided by experts, and to decide when bad information is being delivered as premium scientific knowledge. Practice in reading articles generated by scientists for the public will allow them to become better critical readers of the material. In a paper presented at a meeting of the American Chemical Society, Harry N. Holmes stated this exact idea: “General chemistry . . . should be just what the name implies---a general treatment including traditional descriptive chemistry . . . Above all, even above the accumulation of facts, this course should give training in real scientific thinking” (14). The foundation must be laid carefully, however, because someone who is initially turned-off to science may harbor bad feelings for years afterward.

Part of the problem is the sensationalism of chemistry in the media. The word “chemical” itself creates confusion and panic within communities (7). This negative connotation leads to responses such as what occurred in San Diego, California not too long ago when a busy freeway was closed for the better part of a day by the County Environmental Health Department when a truck carrying labeled bags of iron oxide dropped one bag onto the highway. Convinced that the “chemical” was toxic, hazardous, and would combust in air, officials alerted the public and began to clean up the spill. Iron oxide is commonly referred to as rust, and the city and
citizens of San Diego were in little danger from the spill (10). However, referring to rust with its chemical name suddenly makes it sound dangerous, although a little knowledge would expose otherwise. The media is more interested in ratings than in conveying the facts. Stories show the dangers of new medicines or technologies rather than explain how they work. And, the public falls right in line by believing the dangers of hazardous materials, with names like iron oxide.

Chemistry Education

If the current image of chemistry is not improved, fewer students will want to study chemistry. Because chemistry is the basis of the life sciences, many new technologies, and medicine, those people working in non-science positions in these fields should have a working understanding of the science behind the products and services they offer. Often, the problem begins in high school, but it is perpetuated in the beginning level non-major science courses at the college level. Most colleges and universities have a general education requirement that involves an introductory course in one of the sciences. For professors, these classes are golden opportunities to teach students about the benefits of chemistry, how chemistry relates to their individual fields, and the basic knowledge of chemistry they should have to critically think about the information they find in the media. In essence, a good introductory chemistry course will give students an appreciation for the science that will only help the field of chemistry in the future; after all, those students will become the news reporters talking about chemistry, the politicians making laws and regulations about chemistry, and the customers looking to buy the best chemistry product. Unfortunately, professors around the country are not taking advantage of this opportunity, instead focusing time and money on only those students who are currently pursuing chemistry degrees.
A report presented in *Chemical and Engineering News* found that courses for the non-major were significantly below the standards that the chemistry degree courses were held to within individual departments (7). The classes were large and the students had very little opportunity to interact with their professors. When asked about the material, students described the classes as being “boring” and consisting of long lectures containing information that they felt was irrelevant. The extent and quality of the laboratory period was also criticized, if there was a laboratory at all. Many of the non-major students all responded with the same idea: Why do I need to learn this? The reasons to learn material that may seem irrelevant to the non-major can be difficult to justify, but it is the job of the professor to try none-the-less. This is one major root of the problem; chemistry is unpopular because professors cannot explain why students should learn what they are teaching. Concerning this responsibility, Joseph J. Lagowski of the University of Texas at Austin stated, “We don’t do it well. And then we are unhappy because our discipline is going down the tubes” (7). Glenn A. Crosby of Washington State University also spoke to the benefits of engaging non-majors in discussion and lectures that would interest and benefit them. He said, “We should be teaching chemistry for what it is, something that without the knowledge of it, one cannot live in psychological comfort in the last half of the 20th century and certainly not in the 21st” (7).

The problem then becomes: what is the best way to teach an undergraduate non-major course in chemistry? Perhaps one of the biggest mistakes is to teach the course without a laboratory section. The laboratory can provide some of the most interesting experiences the students may have all year; and by participating in laboratory, the students can gain a better understanding of the concepts presented in lecture. In spite of these facts, laboratory sections have been eliminated from chemistry courses in many universities. As Hawkes wrote, it can
save money for the department; and that money could be used elsewhere: research, departmental major courses, etc. Also, students often view laboratory as a long, boring, waste of time. In order to pacify these students, laboratory is removed from the curriculum. While Hawkes is correct that some laboratories can be a waste of money and time, too many studies have found they benefit the students’ abilities to learn the material. The bottom line is that a laboratory has to be designed and managed appropriately in order to truly benefit the students. As the issue was presented in a recent article, “Practical work in chemistry provides the personal experience. To be deprived of it is a handicap to learning: the learner is like a deaf person in a music course” (2).

Bloomsburg University – A Successful Example

A new chemistry course at Bloomsburg University in Bloomsburg, Pennsylvania aimed to create an introductory chemistry course including a laboratory that would be well received by the student body, as well as groundbreaking in the concepts it would teach to non-majors (1). The general education requirement at Bloomsburg University included 12 credits from science courses, but there were no laboratory requirements at the time this new course was created. Professors and counselors reported that students usually chose “the easiest” courses they can find, because they did not have to complete any from a certain discipline. It was believed that if a laboratory course were added to the curriculum, the administration would probably need to support the addition of a laboratory requirement in order to find students for the new courses.

The course, entitled “Frontiers in Science and Technology” was designed to deconstruct common misconceptions about chemistry, while teaching the students interesting laboratory techniques and fascinating but relevant material. Some of the misconceptions that Emeric Shultz, the professor who developed the new course, cited were: chemistry is independent of
biology, laboratory and lecture are two separate entities, and that the laboratory is linear with a predetermined outcome. Shultz broke the mold by teaching that chemistry is dependent on biology, and other sciences and disciplines. Hence, students in different fields could find relevancy in chemistry. He also contrived to find the connection between lecture and laboratory; Shultz wrote, “I have stopped being amazed at how students can compartmentalize the laboratory and lecture experiences despite heroic efforts on our part to connect them.” Shultz insisted on continually drawing connections between the two. He physically broke this compartmentalization by allowing some lecture hours to be devoted to laboratory and vice versa. In this way, long but interesting experiments could be performed over several sessions in a week, and the next time some laboratory period would be given to the lecture time. One of the most important steps Shultz made is to show the students that laboratory is not necessarily linear, with a “cookbook” set of instructions that micromanage how students piece things together to obtain a certain outcome. By keeping the pre-lab short and to the point, Shultz cut down on much of the “boring” part of laboratory and started the students with immediate hands-on activities. In the end, the students were asked to observe and interpret the outcome, instead of comparing their results to the desired result stated in a laboratory manual. In this way, the students were allowed to experience science discovery---the one thing that Shultz says is “the heart and soul of the scientific enterprise.”

The “Frontiers in Science” course had been offered twice at the time Shultz’s article was written, and it had been evaluated carefully. On a scale of one to eleven, students averaged an increase of four points when they evaluated their confidence in doing laboratory science. Both classes’ evaluations showed that students felt they had a more positive attitude towards science and had more confidence in learning science in general. In a group of 194 students, only 14 felt
that they experienced a neutral or negative change in their confidence in laboratory science. The most convincing piece of data from the evaluation is that 75% of students said that the part of the course they liked best was the laboratory.

Shultz states that in order for students to benefit from laboratories, “we must use the potential of the laboratory experience to its fullest.” He found that many students remarked on their ability to work with “high tech stuff” in the laboratory. Shultz is a proponent of using advanced equipment and complex techniques for first year students because it shows that the professor has confidence in the student and that the professor values the student’s learning experience instead of valuing another seat in the lecture hall which needs to be filled. Finally, Shultz comments that he would trade a 3 credit lecture course for a 3 credit laboratory course, even if the class would cover less material. At the beginning level for the non-major, content should be viewed qualitatively, not quantitatively. If the students enjoy the experience, they will retain more information, and they will have a positive memory of chemistry that they will carry with them throughout their own careers.

**Chemistry Teaching Methods**

In a summary of chemistry teaching methods used around the country, Elliot R. Downing found that the laboratory method demonstrated superior results to both the lecture or demonstration method when students were tested over the material in the long-term, according to several cited studies (11). Some of the important questions asked of the students included “What was the purpose of the experiment?” and “What does the experiment prove?” Students in laboratory tested better than students in lecture on these questions. By physically manipulating
the materials, students had a better understanding of what was going on and what scientific principles they were demonstrating than students in courses that were only lecture-based (11).

Avi Hofstein of The Weizmann Institute of Science and Vincent N. Lunetta of The University of Iowa collaborated to create an article about the history of laboratory (15). By reviewing past practices, the two professors critically analyzed the effectiveness of laboratory study, and suggested ways to expand current curriculums at colleges and universities that would include more relevant laboratory sessions. Another major goal of their research was to provide suggestions for researchers to more clearly clarify the “role of the laboratory in science education” (15). For their research, laboratory included any activity “in which students interact with materials to observe phenomena” (15). This is an important distinction; oftentimes, laboratory is associated with long hours, dangerous chemicals, and a myriad of instruments. Laboratory does not have to be so complicated. Allowing students to work with fast, simple experiments or even simply manipulating models can be beneficial without being expensive or time consuming.

Hofstein and Lunetta acknowledge that there have been many studies that have compared the laboratory technique with other teaching techniques, including lecture, demonstration, and computer simulation techniques. Yet, they feel that the design of many of these investigations and the choice of the outcome measures may be inadequate in evaluating the benefits of laboratory work. Some of these inadequacies include poor choices in the selection and control of variables and the size of the groups examined. Oftentimes, researchers failed to include variables that were descriptive of student abilities and aptitudes, prior laboratory experience, the diversity and size of the group examined, and the kinds of instruments the students were using. Standardized achievement instruments that were created to measure the abilities of students in a
general chemistry course, not specifically a laboratory section, were often used to gauge the improvement of student abilities in the laboratory part alone. The researchers felt that many of the journal articles that spoke poorly of laboratory work had not properly evaluated the work. Thirty of those articles that were examined drew absolutely no connections between the type of evaluation used and the actual laboratory procedure.

Hofstein and Lunetta also described some of the benefits of laboratory experience for non-majors in great detail (15). Students were able to develop skills that they could use in other disciplines by participating in a laboratory; they would not gain those same skills by merely participating in a lecture course. Some of these mental skills include creative thinking, problem-solving, scientific thinking, invention, and discovery. Students developed creativity by participating in open-ended laboratories, and trouble-shooting in these laboratories allowed them to discover their own solutions to problems they encountered. Invention and discovery are two ways to describe learning; invention is the introduction of a certain concept or theory to the students, and discovery is students investigating the statement in the physical world. Laboratory can allow students to discover what the teacher professes over and over. Allowing students to "discover" a theory in laboratory first and learn the theory in lecture second give the student more ownership to the information in the classroom.

Finally, Hofstein and Lunetta found that there were many practical skills that students could gain from laboratory that would be applicable in almost any other field. These included: communication, observation, investigation, reporting, manipulation, and discipline. Many times, students are required to work in groups, allowing them an opportunity to communicate their ideas and thoughts to their peers. Also, students observe the physical results happening on the laboratory bench, and can draw abstract conclusions from them, developing complex
investigation skills. When students are required to keep a laboratory notebook, good reporting of those observed phenomena, as well as good writing, are encouraged. Finally, students learn discipline in that some of the instruments require careful and exact manipulation, as well as patience, in order to find the desired result. Sometimes, the desired result is not discovered, and students are allowed to feel exactly what scientists all over the world feel everyday. The experiments do not always end the way you want them too, and this lesson will be true in every line of work. Students learn to accept certain failures and try again.

**Making a Better Laboratory Experience**

Once a department embraces the laboratory as a necessary part of the non-major course, the next question is: how do we make the laboratory part of the course practical, affordable, and engaging for the students? In a comparison study between laboratory courses in the United States and in Germany, researchers found that the laboratory experiences in the United States overwhelmingly do not serve as the basis for any future lectures (8). The experiences the American students had in laboratory were often self-contained without direct correlation to the other part of the classroom. And, the conclusions about the laboratory were provided ahead of time, so students simply had to reach the predetermined answer. These were exactly the problems the professors in many chemistry courses faced, yet they persisted when the general population of chemical educators indicated that a cookbook approach to chemistry was not beneficial. The conclusions were that many of the techniques the German students were exposed to were beneficial and that many of these techniques were the same procedures that American professors desired to use in their classrooms. In order to make laboratory more beneficial in America, the researchers proposed that there should be more flexibility to laboratory, that
laboratory should further the understanding of concepts presented in lecture, that students should be allowed to tamper with set instructions in order to investigate chemical properties (without cookbook instructions), and that professors and laboratory assistants should be available to assist students with obtaining the necessary information to finish a laboratory procedure on their own and not by simply repeating what the professor has done. The major conclusion was that having students parrot the actions of a professor or go through the motions of an experiment by simply copying steps from a manual does not help the students learn. Allowing them control over each step in an experiment, and allowing them to fail and explain why, is more important than requiring that they duplicate the results of an expert.

Another way to view chemistry classes when constructing a laboratory course for non-majors is to remember that they are part of the general education requirements (9). This means that while everyone might be required to take a science, chemistry is part of a much larger group of disciplines that these students will not be pursuing. It is important to keep the goal of general education in mind when constructing a class that will meet those needs, as in a liberal education. A liberally educated person by definition is one who is free to seek his or her own education in order to prepare for a fulfilling and productive life. Although this definition requires that students are given a "taste" for chemistry in order to make them more productive and curious in their own professions, oftentimes professors use the general chemistry course to profess difficult concepts in large quantities in short amounts of time. These professors are, in essence, overqualified for the job that is required of them. While the detail-oriented laboratory is necessary for chemistry majors, non-majors require much simpler and straightforward coursework.
Despite harsh criticism of laboratory courses, most professors agree that laboratory is a beneficial part of the chemistry curriculum, even for undergraduate non-major courses. Laboratory provides educators with the opportunity to battle apathy towards the sciences and science illiteracy in the general public. By creating a laboratory that is interesting, students can gain an appreciation for science that will continue throughout their lives. Laboratory can also aid professors in conveying difficult concepts through simple but meaningful experiments, providing students with a greater comprehension of the course material. And, adding laboratory limits the amount of coursework that can be covered in a semester, which may be the right push for some overqualified professors; coursework can be kept relevant and interesting for students who do not need deep understanding of the concepts. Finally, laboratory can provide students with skills that they will apply to their own chosen professions, including improved communication and instrument manipulation, as well as practice in writing and observation. Lecture can be more interesting by allowing students discovery in the laboratory first, which is emphasized by the topics covered in lecture. When a laboratory is added to a course, the entire course becomes more beneficial to the student who is a non-major. Clearly, educators should take note of these benefits and structure laboratory courses that can employ the techniques necessary to benefit all students, not just those who are majoring in chemistry--doing so will ensure the future success of the field.

**Taking Action**

The CHEM 100 People and Chemistry course at Ball State University does not include a laboratory section to accompany the lecture. If administrators took note of the many benefits of laboratory teaching presented in recent research, perhaps a laboratory would be added to this course. If such a change were made, care would have to be taken in the choosing of laboratory
experiments. The course is usually taken by non-majors, but is required of other disciplines including those in radiology and apparel design. Many students also take this course as one of the general science requirements of the core curriculum. The lecture section must cover material that is required by the students who take the course as part of their major requirements, while remaining relevant to those students who just need a general education chemistry course. Experiments should reinforce what is being taught in the lecture.

I propose to create a laboratory section that utilizes all of the benefits discussed above. The experiments should cover a wide range of topics; this variety can keep up the momentum of the course and provide new and interesting topics every week. Also, because this is a general chemistry course, it would not be necessary to perform a new experiment every week. The laboratory time could be utilized to review mathematics skills that students are expected to know and use without losing time from lecture, for example. This will help students feel better prepared for the exams, and allow them to succeed in a difficult course. Research shows that a minimal pre-lab where students are allowed to quickly move to the hands-on part of the laboratory is more popular than long questions and problem sets that they are unequipped to answer before the actual experiment. I suggest that a better test of the material would be a more in-depth analysis of the results with questions and problems after experimentation. Oftentimes, departments hesitate to spend large amounts of money on these courses, but simple experiments can often be cost effective and yet remain beneficial to students. The following experiments that I have suggested have been chosen with cost-effectiveness in mind.

Implementing a laboratory with the CHEM 100 People and Chemistry course at Ball State University would improve interest in science, increase understanding of complex material, and create an appreciation for chemistry for students in non-science fields.
Appendix

The following suggestions are ideas for laboratory experiments that could be added to the current CHEM 100 People and Chemistry course at Ball State University or any other similar undergraduate non-major course at the college level.

1. **Boiling Point Elevation/Freezing Point Depression**

   This topic is familiar to anyone living in regions where it snows. Salt is placed on roadways to prevent icy buildup. It is often covered in beginning chemistry courses. The accompanying experiments can be a simple and fun way to begin the semester. These experiments could involve monitoring the boiling point of water in beakers with and without the addition of salt. To examine freezing point depression, a popular route is to make ice cream. The materials needed would only include heavy duty freezer zip-lock bags, plastic containers, ice, rock salt, and the ingredients of simple ice cream (milk, sugar, vanilla). This experiment is popular because the students get to make food—it is a rarity to eat in the laboratory.

2. **Examining pH and Acid/Base Reactions**

   Examining pH and acid/base reactions is pertinent to many types of nursing (especially when considering buffer solutions like that employed in blood), as well as food chemistry (16). These reactions can also be easy to accomplish, while providing a distinct result. Performing a titration might not be the best idea in an introductory class; although it clearly shows how to calculate concentration and often employs acid/base properties, it is a slow process that requires care and patience. It is also rather unexciting. Some more exploratory methods could include tasting certain acidic and basic foods; acids have a sour taste, and bases have a bitter taste (17).
Also, bases feel slippery, as observed with soaps. Both acids and bases change the colors of plant dyes; acid will change litmus paper from blue to red and base will change red litmus to blue. Acids will react with certain metals and produce hydrogen gas. The neutralization of an acid by a base will result in the formation of a salt (18). Several simple neutralizations could be performed along with sensory testing. Also, aqueous acids and bases conduct electricity. Finally, adding drops of an acid or a base to a buffer solution will not change the pH. All of these properties of acids and bases could be examined in a single laboratory session. The laboratory would remain interesting because there would be several different kinds of tests to perform, and it would be a good introduction to a lecture on pH.

3. Making Soap

By talking to students who have taken beginning level courses in laboratory chemistry, it is easy to see why students enjoy making soap. The reaction is exciting even for non-majors! This reaction, saponification, is the reaction of a base with an oil or a fat to form soap (17). Soaps are able to clean because they emulsify substances that are insoluble and hold them in suspension in water (18). This is due to their structure: one end of the soap molecule is polar and the other end is nonpolar, giving them the ability to be soluble in water and oils concurrently. This quality is often termed amphipathic. This experiment provides a basis for discussion about polarity: what polarity is, which molecules have it, and what happens when a molecule is both polar and nonpolar. And, it is a fairly quick and cheap experiment requiring little more than vegetable oil, a sodium hydroxide solution (base), and salt water. Use of sodium hydroxide also allows for a discussion about laboratory safety, since the base will corrode tissue, even at a low
concentration. However, it is not so dangerous that professors should hesitate to use it in an introductory class.

4. Vitamin C Content in Food Samples

Exploring food content is a relevant topic for nutritionists, nurses, and even those students simply interested in good health. Vitamin C is one of the most abundant vitamins; it can be found in fresh fruits and vegetables and also in juices. In its pure form, vitamin C is colorless, water-soluble, and is quickly destroyed by air oxidation (18). A comparison of the vitamin C concentration can be performed easily with simple materials. Again, titrations could be employed for exact values, but these students need a more general understanding of the science. Keeping the laboratory simple and interesting will benefit the students more than the long, arduous process of titrating samples. Several different samples of vitamin C could be tested, including an actual vitamin tablet, cranberry juice, and orange juice. By combining iodine and starch (a spray starch used for ironing would work), a blue color will result as the iodine reacts with the starch (16). Addition of a vitamin C sample would result in a reduction of the blue color because the iodine would oxidize the vitamin C, leaving less iodine to react with the starch. Varying colors of blue could then be used to determine which samples contain the most Vitamin C.

5. Chromatography

Chromatography is a process of separation in which a sample is carried by a liquid or gas through a stationary phase resulting in a range of distribution of the sample components (17). Simple chromatography techniques can be used to separate the dyes in food coloring or ink (18).
Also, complicated instruments employ chromatography techniques, and this may be a good topic for a demonstration and discussion about industrial chemistry. If these instruments are available at the institution, it is not without reason to consider allowing these students to run experiments using High Performance Liquid Chromatography or Gas Chromatography. After all, many students were impressed that they would be able to use such equipment at an early level, and careful instruction and observation would allow for one or two laboratories to be more complicated and "high tech." A simple technique is to use a felt-tip black pen to draw a small spot on chromatography paper about an inch above the bottom, and then to place the bottom of the chromatography paper in an acetone solution (18). The paper will draw the acetone up, and the ink will separate into individual color components along the length of the paper. This technique even works with cheaper coffee filters, if there are budget constraints.

6. The Synthesis of Aspirin

Aspirin, the common name for acetyl salicylic acid, is commonly used as a pain reliever and fever reducer (17). Most people have had some sort of experience with aspirin, so this will be relevant to students; aspirin is the most widely used drug, with a daily consumption in the United States equal to 20 tons. This experiment could also provide a platform for discussion about the synthesis of much more complicated drugs. The synthesis of aspirin is fairly simple, really only requiring a careful combination of sulfuric acid, salicylic acid, acetic anhydride, and ice water in a test tube that is heated in a hot water bath (18). Sulfuric acid and acetic anhydride are both corrosive to the body, but careful manipulation of these substances would ensure that students can avoid danger.
REFERENCES


