

ConfChem Conference on Educating the Next Generation: Green and Sustainable Chemistry—Development of Greener Laboratory Manuals for Introductory Chemistry Courses

Sally A. Henrie*

Department of Chemistry, Union University, Jackson, Tennessee 38305, United States

S Supporting Information

ABSTRACT: The intent of this project was focused on designing appealing and educationally effective “greener” laboratory manuals for traditional introductory chemistry courses. Targeted courses were traditional and homeschool first-year high school chemistry courses and regular and web-based college chemistry courses for those who are not science majors. The manuals include engaging experiments that reinforce the concepts taught in the particular introductory chemistry course while eliminating the need for hazardous waste disposal. A kit was developed with eScienceLabs for the Web-based and homeschool manuals. Supplementary teachers’ manuals have also been produced that include answers to pre-lab and post-lab questions in text. These include a unified materials section with an index of supplies. A web site was developed to make the Green Chemistry Laboratory Manual prepared for a traditional high school course available to high school chemistry teachers.



KEYWORDS: High School/Introductory Chemistry, First-Year Undergraduate/General, Curriculum, Laboratory Instruction, Safety/Hazards, Distance Learning/Self Instruction, Green Chemistry

This communication introduces the *Green Chemistry Laboratory Manuals* developed for high school and introductory college courses. This work evolved from the recognition of the challenges involved in running high school-level chemistry laboratories. These challenges include safety, lack of laboratory space, and the rising costs of both materials and hazardous waste disposal. Undergraduate students, including six considering careers in secondary chemistry education, developed the experiments. They completed their research with a better understanding of the nascent field of green chemistry and its importance.

The project began in 2002 with a needs analysis. A questionnaire was developed and distributed to 11 high school chemistry teachers. A follow-up interview was made with each teacher to further clarify needs. Additionally, several current high school chemistry textbooks and materials related to green chemistry experiments were examined. Analysis of the information indicated there had been a major shift to include the majority of high school students in chemistry classes, but the curriculum has not been revised to accommodate increased learner ability variance. The teachers surveyed reported that this makes it more difficult to teach the material. It was also determined that both block and traditional schedules would need to be accommodated. After considering all of the

information obtained, 19 traditional topics such as stoichiometry and gas laws were chosen for inclusion in the original manual and the initial criteria were set as follows:

- Require 45 min or less to perform
- Reduce or eliminate toxic organic solvents
- Reduce or eliminate hazardous heavy metals
- Cost less than comparable labs
- Re-emphasize material covered in class
- Incorporate relational and inquiry-based learning
- Interest the typical high school student
- Use and teach basic lab techniques

Developing laboratory experiments that met all of the established criteria proved challenging for many of the topics, especially those that traditionally used hazardous heavy metals. Even after alternatives were found, testing by high school teachers often revealed other problems not initially considered. For example, the stoichiometry experiment at first did not have enough of a change in molar mass between the reactants and the calcium carbonate product for students to easily tell that the new product was formed. Replacing sodium carbonate with potassium carbonate and adjusting the quantities of the reactants used solved this problem. Field testing also showed

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four additional topics were needed. A full list of topics, the experiment titles, and additional features deemed desirable for the laboratory manuals are available in the Supporting Information.

While work was progressing on the manual, the Tennessee Department of the Environment and Conservation (TDEC) initiated a twofold project to first remove hazardous waste and materials from high schools across the region and to prevent the future acquisition of hazardous materials. It was recognized that using greener experiments would be one way to realize the project's second goal. Through working with TDEC, presenting this research and field testing, the original premise that a greener manual was needed was overwhelmingly reinforced.¹ This led to determining how the manual should be disseminated. It was decided to create a web site where teachers can request a password to view all of the labs or purchase a CD containing the manuals as Word documents.² Teachers are granted limited permission to adapt the labs for their particular situation. For example, students may need to use a different size beaker or the teacher may want to revise the questions. A one-day workshop has been designed that acquaints teachers with many of the experiments and is available on the web site as well.

As the manual was disseminated, development of additional types of greener chemistry laboratory manuals was frequently requested. This led to development of "greener" manuals for homeschool and both traditional and web-based introductory college chemistry courses. When developing these manuals, it was recognized that the best option would be to make a fairly inclusive materials and supplies kit available, but this would require unfeasible resources. eScience Labs learned about this work and became interested in creating and marketing kits based on these experiments.³ This has provided a powerful additional means to introduce students to green chemistry.

Greener AP (advanced placement) and general chemistry manuals are currently being developed with an additional goal of more aggressively teaching students the philosophy of green chemistry. This is often accomplished through inquiry learning experiences.

■ CONCLUSION

Through encouraging college students, especially those planning to teach high school chemistry, to engage in research to develop these experiments, an increased knowledge of the benefits of green chemistry was attained by not only the college students and their peers, but potentially also by students they will later teach. This paper was discussed from June 11 to June 17, 2010 during the spring 2010 ConfChem conference, *Educating the Next Generation: Green and Sustainable Chemistry*. ConfChem conferences are hosted by the ACS DivCHED Committee on Computers in Chemical Education (CCCE), are open to the public, and can be accessed at the CCCE web site, <http://www.ccce.divched.org/>.

■ ASSOCIATED CONTENT

§ Supporting Information

The revised ConfChem paper. This material is available via the Internet at <http://pubs.acs.org>.

■ AUTHOR INFORMATION

Corresponding Author

*E-mail: shenrie@uu.edu.

Notes

The authors declare no competing financial interest.

■ REFERENCES

- (1) Three of the experiments may be found at www.tennessee.gov/environment/sc3/greenchemistry.shtml.
- (2) Green Chemistry Labs. www.greenchemistrylabs.com (accessed Nov 2012).
- (3) Inclusive kits are available through the website: www.eScienceLabs.com (accessed Nov 2012).