Using Technology Equipment to Teach Chemistry Laboratory Exercises in Community Colleges

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Abstract

The drive to attract students into science and technology careers at all levels has led to creative programs and efforts across the country. At Hillsborough Community College in Tampa Florida, a new associate in science manufacturing technology degree program focused on high tech manufacturing processes and skills has been developed. The lab facilities include a high-end vacuum technology and systems laboratory. Training on the new equipment was offered to both the technology and science faculty members across the state as part of an NSF ATE grant. As a result of this vacuum system training, science faculty worked with technical faculty to develop several laboratory activities for general college chemistry and organic chemistry laboratories using the vacuum systems. Multiple stations allow the chemistry students to work in small groups as in any traditional chemistry laboratory. Student exposure with multiple chemistry experiments using the vacuum training equipment will provide reinforcement and comfort with the seemingly complicated equipment. The objective of the chemistry activities in the vacuum laboratory are to familiarize students with practical and real-life applications of the chemistry they learn in a pure science class in industrial type settings and to peak their interest in science and technology career paths. An overview of the chemistry demonstrations and experiments using the vacuum technology equipment will be provided in addition to the science student impressions to these alternative laboratories.

Background

There is no need to belabor the issue of decreasing enrollments in college and university mathematics, technology, science and engineering programs. There is a critical need for trained and educated workers in these areas in every part of the country. However, as a nation, there are fewer and fewer graduates from two- and four-year institutions earning degrees in science, engineering, technology and even business. Starting new programs to support new technologies, and maintaining a critical mass of students in important existing programs is a constant effort that requires significant time and energy in science, engineering and technology programs across the country.

There is a plethora of recruiting tips and tricks. This paper outlines the basis of one in-house program at HCC. The Brandon Campus has developed a new Manufacturing Technology A.S. program with a focus on high technology manufacturing. Part of the program includes courses

dealing with vacuum technology, and therefore, a state-of-the-art Vacuum Technology and Systems Laboratory has been developed. To increase exposure of this laboratory facility several laboratory exercises for different Chemistry classes have been developed. The Chemistry Lab students meet in the Vacuum Technology Lab to perform experiments related to the topics in Chemistry but use the vacuum equipment the technology laboratory. To date, 2 exercises have been developed for the Inorganic Chemistry courses (CHM 1045 and CHM 1046) and 1 activity for Organic Chemistry (CHM 2211). The potential payback is blatantly obvious: Recruit undeclared students already somewhat interested in science (chemistry) and technology into the new Manufacturing Technology program.

A parallel effort to increase exposure of the new laboratory facilities at HCC to the local engineering college and technical community has been initiated. To enhance the relationship between HCC and the College of Engineering at the neighboring University of South Florida (USF), a graduate Engineering Class in Modeling and Analysis was invited to the Vacuum Tech Laboratory to use the equipment to acquire data to validate and/or calibrate a mathematical model that they were developing for class. To increase the awareness of the local technical community of the new facilities, HCC has entered into an arrangement with a national vacuum equipment company to offer training courses in the HCC Vacuum Technology and Systems Laboratory.

Vacuum Technology and Systems Laboratory

Although the Vacuum Technology Laboratory has a variety of equipment used for training students, 4 student workstations, each have a modular MKS Vacuum Training System are the centerpieces of most student training, and particularly the exercises discussed here today. Each system uses a mechanical pump and a small turbomolecular pump to achieve vacuum environments down to 1×10^{-6} torr. The hardware allows for a variety of experiments and demonstrations to be conducted. There are a several different types of pressure gauges and control valves that are electronically controlled and monitored using a four-channel controller, which also passes all information to Windows-based control and monitoring software. Data can be downloaded to a spreadsheet for analysis, manipulation and reporting. Included in the equipment is a protected glass vacuum chamber, approximately 1.5 inches in diameter and about 10 inches tall. Additionally, each system has a residual gas analyzer that can monitor the composition and partial pressures of the different gasses in the vacuum environment.

Inorganic Chemistry Laboratory Exercises

The lab's vacuum equipment is well suited for producing a low vacuum environment in the range of 10^{-1} Torr. This environment supports well-defined plasma in the presence of an electric field that can be easily generated with commonly available laboratory high voltage power supplies. The plasma is the springboard for a lesson on molecular ionization and electronic emissions, as well as the properties and utility of plasmas in industrial settings. The accompanying experiment provides students with an opportunity to determine the optimum flow rate, pressure and voltage for generating plasma under controlled conditions.

The vacuum system's variable mass flow controller can be used to maintain the pressure when the chamber is exposed to atmospheric gases. The mechanics of using the mass flow controller

to change the pressure and the variable voltage source allows the students to "tune in" or light the plasma over a range of pressures using different voltages. The chemistry of the ionization and the energization phenomena in the plasma, properties of the plasma, and the properties of different substances in a vacuum environment can be explored. Additionally, the concept of controlling an experiment by adjusting operating parameters is introduced. This experiment differs from the typical introductory chemistry verification experiments in that students explore, discover, and apply knowledge gained during the experiment. A primary outcome of this experiment is for students to see some of the practical uses of chemistry course content. Students are introduced to several plasma applications through the background section of the experiment and the accompanying power point presentation. Students follow up this introduction to practical applications by researching and presenting one high-tech plasma application. This exploration enables students to go beyond the routine emission spectroscopy identification applications.

Other activities include the hands-on version of the traditional chemistry and physics vacuum pump demonstrations of some of the properties of materials in vacuum environments (transmission of sound and light, speed of falling objects in a vacuum, triple point observations, and gas pressure-volume behavior, i.e., Boyle's Law). The Vacuum Technology lab has 6 single stage rotary vane pumps that the students can use to conduct these demonstrations and experiments themselves. Boyle's Law Experiment offers the opportunity to not only make observation but record, plot, and analyze data. Although the experiments and demonstrations with the single stage rotary vane pumps are identical to the ones that chemistry and physics students might do in their science labs, working in the Vacuum Technology Lab gives them another exposure to the other high tech equipment that also resides the lab.

Organic Chemistry Laboratory Exercises

A laboratory activity in the Vacuum Technology Laboratory for second semester Organic Class (CHM 2211) uses the same Vacuum Trainers in a high vacuum configuration that includes the auxiliary Residual Gas Analyzer (RGA). The activity is an introductory laboratory on Mass Spectrometry analysis and operation. It also introduces the concept of on-line monitoring for industrial or research continuous processes. RGAs are relatively inexpensive mass spectrometers used in commercial low pressure and/or medium vacuum environments to monitor gas composition during processing steps and as a tool for leak detection. The RGAs on the training stations are capable of detecting compounds with atomic masses of up to 100 amu. Any small molecular weight organic compound can be easily introduced into the vacuum chamber using the mass flow controller. The RGA's output is monitored on the same computer that the Vacuum Trainer's controller is connected to, such that the RGA and the controller software can be monitored at the same time. Mass spectrographs can be captured from the screen for reporting purposes. Once again, seeing the mass spectrometer used as a monitoring instrument in a real world applications, instead of an independent analytical instrument is also extremely valuable experience for science students.

In Organic Chemistry, one of the most important concepts for students to understand is structure identification. In this laboratory experiment, students utilized the Vacuum Trainers equipped with RGAs for structure identification of unknown gas samples. Introducing the gas regulated

by the mass flow controller through a sample loop generates the mass spectra of each unknown gas sample. By investigating several small gases, students are able to understand the principles of mass spectral analysis while simultaneously gaining exposure to high-technology instruments. As part of the lab, students are also given the mass spectra of larger molecular weight compounds to utilize their knowledge and skills gained form the hands-on lab, to interpret these more complex structures.

Conclusions

Using the vacuum technology equipment for science laboratories has many possibilities. These examples of using the HCC Vacuum Technology Lab equipment for both Inorganic and Organic Chemistry labs have many advantages. It offer the students an alternative, more applied look at their textbook chemistry. The expanded capabilities of real time monitoring, real time control systems, and computer based data acquisition available in the Vacuum Technology Lab introduce the students to these important and crucial aspects of modern industrial and applied chemistry. For learning retention, it is critical that learners be able to apply what is taught in some meaningful context. These experiments are a true integration of general education chemistry courses with technical courses and provide students with the opportunity to conduct experiments in a more real-life setting and see the applications of chemistry content in the workplace.

Biographic Information

MARILYN BARGER received her B.S. degree in Chemistry from Agnes Scott College and B.S. and Ph.D. in Civil and Environmental Engineering from the University of South Florida, Tamp Florida. Dr. Barger has over 15 years teaching in Engineering and Technology related programs throughout the country. She is a registered professional engineer in the state of Florida and has been an active member of ASEE for over 10 years. She is currently an associate professor at Hillsborough Community College, Tampa Florida and a Research Associate at the University of South Florida.

ELIZABETH MCCULLOUGH has a B.S. degree in Biochemistry and Chemistry from Hood College; Frederick, MD and a M.S. in Biochemistry from the University of Maryland. She has twelve years of experience teaching in a variety of educational levels and settings including high school, community college, private college and public university level. Currently, Ms. McCullough is a chemistry professor at Hillsborough Community College, Tampa, FL.

KATHLEEN CARVHLHO received her B.S. in chemistry from Valdosta State University (1996) and her Ph.D. in chemistry from the University of South Florida (2000). Her research interests include water quality, heavy metals in the environment, phytoremediation of heavy metals by aquatic species, and chemical and environmental education. She serves as the vice-chair for the Pinellas Sub-Section and the chairperson of the Education Committee for the Tampa Bay Section of the American Chemical Society. She is currently a Visiting Assistant Professor of Chemistry in the Department of Environmental Science and Policy at the University of South Florida St. Petersburg.

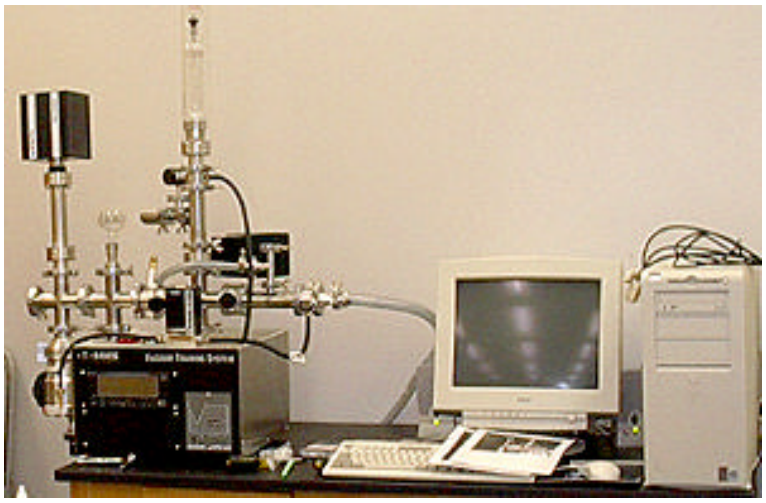

Figure 1. MKS Vacuum Training System at HCC

Figure 2. Air Plasma in Vacuum Trainer

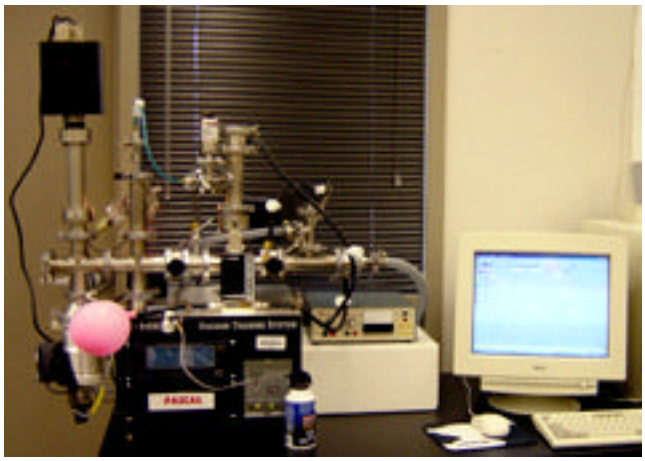

Figure 3. Vacuum Trainer Set Up for Mass Spectrometry Experiment