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ARTICLE *in* JOURNAL OF CHEMICAL EDUCATION · JUNE 2014

Impact Factor: 1.11

JOURNAL OF CHEMICAL EDUCATION

Communication

pubs.acs.org/jchemeduc

Summer Enrichment Programs To Foster Interest in STEM Education for Students with Blindness or Low Vision

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ABSTRACT: Hands-on science enrichment experiences can be limited for students with blindness or low vision (BLV). This manuscript describes recent hands-on summer enrichment programs held for BLV students. Also presented are innovative technologies that were developed to provide spoken quantitative feedback for BLV students engaged in hands-on science learning activities. Some low-tech polymer synthesis activities that were designed to be very tactile and hands-on in scope are also discussed. These activities were presented in several recent workshops and can be reproduced and implemented as part of a chemistry course in high school or used as hands-on demonstrations for all learners.

KEYWORDS: *High School/Introductory Chemistry, First-Year Undergraduate/General, Curriculum, Laboratory Instruction, Hands-On Learning/Manipulatives, Computer-Based Learning, Polymerization, pH, Thermodynamics*

BACKGROUND

Hands-on science learning has been proven to be beneficial for students enrolled in science, technology, engineering, and mathematics (STEM) courses of study.[1] According to Piaget, people learn by doing.[2] Therefore, performing hands-on activities can foster increased interest in a given field.[1,3] Hands-on learning is particularly important for students participating in STEM related courses such as chemistry, biology, and physics. This "learn by doing" assertion is no less important for students with blindness or low vision (BLV).[4] In recent years, there have been a number of hands-on science enrichment programs for students with BLV. Enrichment activities sponsored by the National Federation of the Blind include the 2004−2006 Rocket-on science academies for grades 9−12, Circle of Life program for grades 5−8, National Federation of the Blind Youth Slam 2007, 2009, and 2011, and the 2013 STEM-X experience.[5]

Several camps have been hosted by Dennis Fantin who is a totally blind lecturer at Cal Poly Institute of Technology in San Luis Obisbo, CA. Fantin's camps include hands-on activities such as feeling the difference between saturated and unsaturated fats extracted from sandwich cookies and using the human tongue to detect the differences between weak acids and bases such as lemon juice and antacid tablets.[6] Another summer enrichment program was hosted by Henry Wedler, a graduate student in chemistry at UC-Davis, at Enchanted Hills Camp near Napa, CA. In this program, students used their olfactory sense as an indicator in acid−base titrations and in the synthesis of various esters.[7] Further work done by Wedler et al. describes a series of summer enrichment programs for students with BLV during the summers of 2011 and 2012.[8] As part of the curriculum these camps included polymer activities similar to those described here. This documents how widely applicable hands-on activities are and illustrates their importance. Another research study, described by Supalo, Isaacson, and Lombardi, featured the use of the Sci-Voice Talking LabQuest that provided a direct hands-on way for students with BLV to collect scientific data in a quantitative way.[9] This work reported on the field testing of the Sci-Voice Talking LabQuest at the 2011 NFB Youth Slam event. In this workshop, the Sci-Voice Talking LabQuest was found to be beneficial to this group of students. Feedback on improvements for the user interface was collected. This population of approximately 90 participants indicated a positive experience with the Sci-Voice Talking LabQuest and indicated that they would consider taking science laboratory classes in the future using the technology. These (and other local programs sponsored by blindness interest groups) are all productive experiences for students with BLV. All of these programs serve as illustrative examples of how students with blindness or low vision can be successfully integrated into hands-on summer enrichment programs.

It is a common misconception among both sighted and BLV persons that science is too visual in nature, and thus not accessible to persons with BLV. However, one of us (C.A.S., himself totally blind), along with other blind scientists that came before him, namely, H. David Wohlers, William J. Skawinski, and Judith Summers-Gates, demonstrates that successful employment in the chemical profession is achievable.[10] The importance of mentoring is critical in the attainment of these endeavors. The value added by hands-on science enrichment programs is important in the future development of young blind professionals. Recognizing this value, the American Association for the Advancement of Science (AAAS) sponsors Project Entry Point. This project places undergraduate students with various disabilities into summer internships in Fortune 500 companies' research and development laboratories.[11] This successful partnership between AAAS and these Fortune 500 companies has opened the doors for numerous successful STEM job placements for students with disabilities. The Entry Point program further illustrates that students with disabilities learn by doing and can be successfully integrated into the STEM workforce.

Published: June 10, 2014

■ SUMMER 2013 WORKSHOPS

In July 2013, the Metropolitan State University of Denver (MSU) hosted an enrichment program for BLV students. The event involved workshops at both MSU and the Colorado Center for the Blind (CCB). BLV students who were enrolled in summer programs at CCB were recruited to participate in this workshop. The 38 participants ranged from middle school to college age. Additionally, several young BLV professionals participated in the science activities presented over the course of 2 days. The MSU workshop was one of the first times the commercially available Sci-Voice Talking LabQuest had been used by an entire class of BLV students from a number of different age groups.

The Sci-Voice Talking LabQuest was developed as part of a National Science Foundation (NSF) Small Business Innovation Research (SBIR) award (1127412 and 0945481).[9,12] Vernier Software & Technology developed the original LabQuest handheld data collection device. Later, Independence Science, a small access technology firm founded by Supalo, developed the text-to-speech software interface for the LabQuest device. Text-to-speech is spoken text that is displayed on a computer screen. The LabQuest is a portable computer that runs on the Linux operating system. The text-to-speech software allows a student with BLV to use the LabQuest product independent of sighted assistance. Prior to this application being commercially available, a BLV student would have to be paired with a sighted partner to read probe readings.

Day 1 Description and Workshop Curriculum

The first day of the workshop was hosted in a forensic science laboratory at MSU. The participants were divided into two sessions occurring at separate times on the same day. The first session was targeted toward high school and college age students. The second session targeted the middle school children. The activities were identical for both groups, but the content discussion was adjusted to be age appropriate. MSU provided free lab space along with glassware and other supplies needed for the hands-on activities.

One of us (A.A.H.), a chemistry faculty member at MSU, led the sessions with assistance from several other MSU chemistry department faculty and students. The activities presented had been developed by undergraduate research students in the Supalo research group at Illinois State University and had previously been field tested in a residential school for the blind. Student feedback from that program was used to improve the experiments that were then featured at the MSU workshop.

A summary of the activities using Vernier Software and Technology published science curriculum follows.

Measurement of pH of Common Household Chemicals. This activity utilized the Sci-Voice Talking LabQuest along with the Vernier pH sensor to measure the pH of acetic acid, lemon juice, soda pop, soapy water, and a sodium bicarbonate solution. The session began with a discussion of laboratory safety. All American Chemical Society safety guidelines pertaining to eye protection and chemical use were followed.[13] A discussion of the concept of pH was presented to the students before they measured the pH of all of the household solutions. Students were encouraged to experiment by mixing their acids and bases as desired. By doing this, they were able to observe the signs of a chemical reaction including fizzing, changes in temperature and smell, and the effect on pH. A postlab discussion was held to share observations with the entire group of students.[14]

Storage Bag Mitten Activity. In this activity zipper storage bags served as "mittens", and various insulating materials (such as cotton socks and air bags) were used to determine the best insulator. The Sci-Voice Talking LabQuest was used in conjunction with a Vernier Software & Technology stainless steel temperature probe. Each participant held the temperature probe in their closed fist for several seconds in order to establish a baseline body temperature. Each student then placed their hand inside a zipper storage bag and positioned the tip of the temperature probe (also inside the bag) in their open palm. The student then placed their bagged palm and temperature probe on top of a "mitten" (a second storage bag filled with an insulating material.). The mitten was then placed on top of an ice pack, and temperature measurements were collected over a 2 min time interval. The results of this experiment were affected by differing techniques between participants, but most groups observed the expected result, which is that air is a better insulator than cotton socks.[15]

Day 2 Description and Workshop Curriculum

The second day of the workshop was hosted at the CCB in Littleton, Colorado.[16] The CCB serves as a training center for blind persons wishing to learn Braille, white cane travel, home management skills, and text-to-speech and other computer skills essential in postsecondary education and in the workplace. The CCB operates on a Piaget philosophy similar to the "learn by doing" philosophy of the National Federation of the Blind. This training program is operated by successful blind professionals, and thus the instructors serve as successful blind mentors for BLV students. In addition to the full-time training program, the CCB hosts enrichment programs such as the hands-on science activities described here. These activities were designed to inspire the blind participants and reinforce the perception that they can pursue STEM career paths of study.

On day 2 of the workshop, the participants were divided into three separate groups of ~10 students to complete a 90 min session focused on polymers. The participants were randomly distributed in terms of age and education level, so the content was kept at a middle school level, though in-depth discussions were frequently prompted by questions from participants. A summary of the day 2 activities follows.

Polymer Introduction and Modeling Activity. Each session began with a discussion about the concept of monomers and polymers followed by a modeling activity. Pop beads, which are commercially available plastic beads that can be popped together to make necklaces and other jewelry, were used as models of polymers with single strands of pop beads representing straight chains. Paper clips were then used to connect several strands of pop beads at random points to simulate cross-linking. Several models with varying degrees of "cross-linking" were passed around, and the students were asked to make observations about how cross-linking affected the properties of the polymer chains. Participants were easily able to relate an increase in cross-linking to an increase in stiffness and the creation of "pores." Following this introduction, three different activities involving polymers were conducted as part of this workshop.

Cross-Linking Polymers Activity. In the next activity, students made their own elastic putty by cross-linking the polymers in regular school glue with borax. Though this experiment used only common household materials, all participants were briefed about safety concerns and all waste materials were collected and disposed of in the chemistry department at Metro State University in Denver. The students were told that white school glue is made up of a polymer called polyvinyl acetate. They were given a sample of glue in a disposable cup along with a stir stick. They were asked to add water to the cup containing glue to give an approximately one-to-one mixture. Then they were given a solution of borax in water in a separate cup. They were instructed to slowly add the borax solution to their glue—water mixtures while stirring and observe any changes. They were immediately able to feel the "stiffening" of the mixture with their fingers, and they understood that this was evidence of the cross-linking of the polyvinyl acetate chains with borate. Students were easily able to relate the actual chemistry experiment to the pop bead models that they had just handled. Participants were encouraged to stir and feel with their fingers the formation of the putty. The participants were instructed to knead their putty to remove the excess water, and then they were permitted to take their putty home with them in plastic bags.

Properties of Cross-Linked Polymers Activity. After making their own cross-linked polymer, the students moved on to an exploration of some interesting commercially available cross-linked polymers. Sodium polyacrylate, the polymer used in disposable diapers, was examined first.[17] The activity began with a discussion about why diapers are effective in keeping babies dry. Most students were aware that diapers are stuffed with cotton, but they were not aware that the cotton is not the main reason that babies stay dry when they are wearing diapers. It is the presence of the nontoxic sodium polyacrylate powder (known as a superabsorbent polymer) that enables diapers to keep moisture away from the baby's skin.

After this introduction, a small sample of sodium polyacrylate was provided to the students in a new set of disposable cups, and the students were instructed to add water gradually. Students were encouraged to touch the polymer as they slowly added water. The students worked in pairs to complete this activity. The amount of water that was absorbed impressed the participants. The tactile sensations they experienced were very noticeable, with many students describing the formation of a "gel" or the fact that the tiny amount of powder absorbed "a lot" of water. The students were reminded of the pop bead polymer models and how the cross-linking of the chains created pockets and these pockets are capable of absorbing a lot of water. The students were then told that this polymer is commonly referred to as Water Lock.[18] This activity provided the students with a very real-world example of the usefulness of cross-linked polymers.

The next polymer that was investigated is commonly referred to as "instant snow".[19] Each group was given a plastic cup with a tiny bit of instant snow powder in the bottom. The students were instructed to feel the powder. They were informed that this powder is derived from the diaper polymer (sodium polyacrylate). The students were asked to predict what would happen if they added water to this polymer (they typically expect it to form a gel like before). They were then instructed to add water to this polymer, again using their fingers to feel the changes that occur. They were easily able to tell that this polymer formed a fluffy powder whereas the diaper polymer formed a gel. They were asked to discuss what this particular polymer could be used for, and most groups easily likened it to snow (some did so only after being told the polymer was white), at which point they were informed that it is, in fact, used as a snow substitute for movies and on ski slopes. They were then asked if this formulation would be a good polymer to use in diapers, and of course they realized that would create a rather large mess.

Each session concluded with a review of the concepts of polymers, cross-linking, and real-world applications of super-absorbent polymers. The students were also informed of a third type of superabsorbent polymer, sodium polyacrylamide (Water Gel), which absorbs water more slowly and can be used to slowly release water to its surroundings. Specific applications such as the use of these crystals in potting soil to provide a slow, steady supply of water and in reptile habitats to provide a source of clean water were discussed.[20] The students were encouraged to seek out this third type of polymer and design some experiments of their own.

■ SUMMARY

The hands-on activities featured over this two-day enrichment experience provided these BLV students a successful exposure to science activities. For some, it was the most positive science-related experience they had ever had in their lifetimes. "Science is my favorite subject", Quinita Thomas said. "Actually, I'm a geek." "I know I'm blind and all that", she said, "but just 'cause I can't see does not mean that I can't mix chemicals together and not be afraid of something exploding up in my eye. This is something I'll definitely remember."[21] One participant, who was attending secondary school at a residential school for the blind, stated that she was not permitted to take chemistry at her school because of her blindness. Her story demonstrates how science educators and school administrators can have misconceptions regarding the capabilities of BLV students in science laboratory classrooms. These activities helped this particular student to realize what is possible. It is testimonies like these that inspire the authors to host enrichment experiences for BLV students. Through hands-on experiences, BLV students can be fully integrated into STEM laboratory classes and can be an essential contributor in a lab group activity. This can be done by means of the successful commercially available text-to-speech interfaces that are designed to be used in the science laboratory classroom. Through the availability of these technologies students with BLV are given the opportunity to collect data in a quantifiable hands-on way.

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Notes

The authors declare the following competing financial interest(s): Independence Science is an access technology development firm completely owned by Cary A. Supalo. Therefore, he owns the text-to-speech software known and referred to as the Sci-Voice Talking LabQuest.

■ ACKNOWLEDGMENTS

The authors thank Tom Mallouk and The Pennsylvania State University, where much of the early development of these activities and technologies took place. Also, Thomas Vogt of the MSU Denver Chemistry Department was instrumental in developing the partnership between MSU and CCB. The MSU Denver Department of Chemistry provided all of the consumables and glassware for the activities, and CCB and MSU generously provided space.

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