Using Adaptive Tools and Techniques To Teach a Class of Students Who Are Blind or Low-Vision

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Approximately 3.8% of Americans are blind or low-vision (BLV). Of these 10 million people, only 1.3 million are working age and employed *(1)*. Little data exist, to date, on the number of BLV people who are employed in the science, technology, engineering, and mathematics (STEM)-related professions, although only 2.7% of the STEM workforce reports a disability of any kind *(2)*. Furthermore, data suggest that fewer than 300 people with any reported disability receive a Ph.D. in a STEM field annually *(1, 3)*. The difficulty of providing a direct and independent laboratory experience to high school and college students with BLV is a major factor in this underrepresentation. As adapted and accessible technology becomes more widely available to students who are BLV, their retention in science courses and ultimately employment expectations in STEM-related fields may rise. Improved laboratory accessibility should significantly increase the self-efficacy of students as they perform laboratory tasks *(4)*. Several new developments, both in accessibility tools and teaching techniques, are now available to facilitate this goal. Many of these advances were brought together for the first time by the National Federation of the Blind at the Jernigan Institute's 2007 Youth Slam *(5)*.

National Federation of the Blind 2007 Youth Slam

The National Federation of the Blind (NFB), the largest organization of people who are BLV in the United States, sponsored three NASA science academies over three consecutive summers, from 2004 to 2006. These summer science academies were promoted in part by the National Center for Blind Youth in Science (NCBYS), an initiative of the NFB–Jernigan Institute. The Jernigan Institute promotes best-practice teaching approaches for the science and mathematics education of children who are BLV; information is available at their Web site *(6)*. The academies were designed for two groups, each accommodating up to twelve students, with three to four blind mentors acting as facilitators. The Circle of Life Academy gave middle school children an opportunity to learn biology and other life science-related topics firsthand through shark dissections and tours of local environmental conservation centers. In the Rocket On! Science Academy, high school students worked with NASA engineers at the Wallops NASA Flight Facility on Wallops Island, Virginia, to assemble and launch a 10 foot NASA sounding rocket *(7)*. These camps evolved into the 2007 NFB Youth Slam. The Youth Slam was four days of hands-on science activities and experiments for 200 students who are BLV from across the United States *(5)*.

Participants were recruited from instructional units or groups of students from different schools and school districts receiving educational services from the same provider or agency. Two hundred applicants, ranging from first-year high school students to first-year college students, were selected to participate. Each student received all room, board, and transportation costs as part of the subsidized Youth Slam attendance package.

The Youth Slam science activities involved rocketry, environmental chemistry, engineering, astronomy, and air science, with up to 12 hours of hands-on laboratory instruction for four mornings. The students selected their preferred track as well as a series of non-track activities, including workshops in advocacy, independent cane travel, college preparation, and additional instruction in Youth Slam areas.

The Youth Slam provided a college-educated BLV working professional as a mentor for every three participants to help facilitate the activities and ensure that students arrived at their respective classes and participated fully in the experiences offered. The mentor and students constituted a pod that slept, ate, and attended all of the same programs together, to promote team-building. Mentors often were not trained scientists nor employed in a scientific or engineering field and were therefore given instruction in laboratory safety by the expert mentors, who were working professional scientists with BLV. Mentors also had the opportunity to ask questions of the experts to ensure they could successfully execute all the procedures.

A series of evening social events was planned for the participants, including outings to the campus recreational center, dances, and game nights. On Wednesday afternoon, all pods visited an exhibit at the National Center for the Blind featuring technology vendors and organizations promoting science education. Several blind professionals with doctoral degrees in STEM fields also spoke about their experiences during a panel discussion.

Adaptive Tools

The tools and techniques demonstrated in the Youth Slam Chemistry Track originated with the Independent Laboratory Access for the Blind (ILAB) project at the Pennsylvania State University. The ILAB project has focused on developing talking tools and adaptive techniques for teaching laboratory chemistry and physics. These tools have been successfully used by students who are BLV in both residential schools for the blind and in mainstream science classrooms. The Youth Slam experience further revealed how these tools and techniques could be successfully implemented in a full classroom of students who are BLV and had minimal sighted assistance.

The tools consisted of new combinations of software and hardware, specially designed tools, and pre-existing devices, both off-the-shelf and modified. Job Access with Speech (JAWS) from Freedom Scientific was paired with Logger Pro 3.5 from Vernier Software and Technology. The combination of a widely used text-to-speech screen reader (JAWS) with data collection software (Logger Pro 3.5) allowed all readings taken by the Vernier temperature and conductivity probes (connected to a JAWS-enabled laptop computer via the Vernier GoLink USB connection) to be read aloud. This setup enabled the participants to observe temperature changes in real time. The interface between JAWS and Logger Pro consisted of specially written script files for JAWS, compatible with versions 7.0 and later and available for free download through the ILAB Web site *(8, 9)*.

The Ohaus Scout Pro balance was used to measure masses and volumes of solutions, in conjunction with both JAWS and Logger Pro. The balance was connected via USB port to a laptop computer equipped with JAWS and Logger Pro, and all measurements were read aloud as students added and withdrew material from containers *(8)*.

The Submersible Audible Light Sensor (SALS), which had previously been tested with the iodine clock reaction, precipitation reactions, and acid–base titrations *(10, 11)*, was used to monitor the progress of reactions. The SALS measures changes in light levels in solution, converting the resistance in a photoconductive probe to an audible tone that changes in pitch as solutions become cloudy or change color during a reaction.

As recommended in the Science Activities for the Visually Impaired/Science Enrichment for Learners with Physical Handicaps (SAVI/SELPH) curriculum, notched syringes calibrated to specific volumes were used for measuring solutions. Plastic cafeteria-style serving trays served as workspace organizers on bench tops, and all work stations were equipped with a computer in a pre-designated location *(12, 13)*.

Curriculum

The laboratory activities used in the Youth Slam Chemistry Track were selected from several American Chemical Society (ACS) educational publications, adapted for BLV participants, and tested for accessibility and safety at Truman State and Penn State. The procedures were provided to participants in large print or Braille. The instructional time included sessions for familiarizing students with the adaptive tools and gave students the opportunity to feel beakers, flasks, ring stands, and other common pieces of laboratory equipment and memorize their forms. The participants were first introduced to the adaptive tools and allowed to try them out within a no-risk, no-pressure laboratory activity. ACS laboratory safety protocols were discussed, such as the importance of not bringing food or drink into the laboratory and the need for safety goggles, as well as locations of safety showers, eye wash stations, and emergency exits. A question-and-answer session with each group of students covered any additional safety concerns, and the need for organization was stressed as well.

Participants were expected to read the laboratory procedures the day before the activity and develop a cooperative learning plan. The learning plan involved task assignment within the group, although some procedures were performed several times to ensure that all participants experienced each activity. On the day of the activity, the participants obtained necessary chemicals from chemical stations located at the end of each bench and cleaned their spaces at the end of each lab session. They also arranged notched syringes, labeled them with raised tape in distinct shapes indicating volumes, and marked beakers to indicate their size, at their workspaces. These raised markings served as tactile means for students to ensure correct quantities were placed in the proper beakers and flasks, as not all participants were able to read Braille. Additionally, data analysis was expected of each pod, as were discussions of mathematical manipulations at the end of sessions.

Properties of Gases

This activity introduced participants to the notion that gases are matter and not simply insubstantial "air" without mass. To bring out preconceived notions of the properties of gases, participants predicted outcomes before attempting the activities. Once the activities were completed, instructors led a classroom discussion about student observations. Several simple experiments concerning Charles's and Boyle's laws, the mass of air, and the exertion of pressure by air were attempted.

The most basic activity had students simply draw air into a syringe, block the end off, and depress the plunger while observing what happened. This exercise demonstrated that pressure and volume are inversely related, and that gas can be compressed. Another activity illustrated that temperature and volume are directly related by submerging one inflated balloon in ice water and another (inflated to the same initial size) in hot water. As the gas cooled, its volume decreased, while the volume increased as the gas was warmed.

The mass of gas was demonstrated by weighing inflated and deflated balloons (easily inflatable balloons) on a talking balance interfaced with Logger Pro and JAWS and comparing the results. The deflated balloon weighed somewhat less, even though, in accordance with Archimedes's principle, it should have weighed the same as the inflated balloon. The observed difference illustrated that the air we breathe is composed of a mixture of gases and that the gas we exhale is enriched in CO_2, which is heavier than nitrogen and oxygen.

To show that air occupies space and exerts pressure, a balloon was placed inside a bottle and inflated. Students noted that as more air entered the balloon, it became harder to push more inside. Then, to show that air exerts pressure in all directions, a small hole was bored in the side of a plastic bottle without a cap. The hole was plugged and the bottle filled with water. The bottle was then inverted; when the plug was removed, water poured out because air could enter the bottle through the hole.

The final experiment, performed by the instructors, demonstrated again that air exerts pressure in all directions. A soda can was partly filled with water and heated on a hotplate until the water inside began to boil. The can was then inverted in cold water, where it immediately contracted, producing a crushed can; this showed that as water vapor inside the can condensed, a partial vacuum was formed inside the can, and the can was crushed by the external atmospheric pressure *(14)*.

Energy Conversion and Conservation

This experiment introduced students to ideas of energy conservation and that different ways of carrying out the same task consume different quantities of energy. Students used three different devices to heat approximately 225 mL of water in a 250 mL beaker: a Bunsen burner, an electric hotplate, and a microwave oven. A talking balance interfaced with Jaws and Logger Pro was used to measure the water. A talking thermometer took initial temperatures and monitored the temperature as it rose during each experiment.

For the Bunsen burner experiment, students first calculated the quantity of energy released by combustion of methane. The instructor provided an estimated value for the delivery rate of the gas from the desktop connection. The students set up the 250 mL beaker for heating with the Bunsen burner flame. The initial water temperature was recorded using a Vernier thermometer, and the temperature change over time was tracked until it rose by 30–50 °C. Students then calculated the quantity of heat absorbed by the water, the quantity of heat released by combustion, and the percent efficiency of the heating process.

The efficiency of heating with a hotplate was determined in a similar manner. First, the students found the energy rating of the hotplate by looking on the device for its power rating in watts. This number was then used to calculate the total quantity of energy released from the hotplate. Water, 225 mL, was heated, and the temperature change was again tracked by using the Vernier temperature probe and Logger Pro.

In the microwave oven experiment, students again found the power rating, in watts, of the oven. The procedure ran the same as with the hotplate, except that the thermometer could not be used in the microwave oven, so initial and final temperature measurements were taken between timed runs in the oven *(15)*. At the end of the experiment, the students discussed the efficiency of each heating method and the impacts of energy use and waste on the environment.

Synthesis of Biodiesel

Students made biodiesel by hydrolyzing vegetable oil with base and then separating the product from the aqueous byproducts by using a separatory funnel. The 100 mL line of a graduated cylinder was marked with masking tape, and the cylinder was then filled with vegetable oil. The tape on the outside of the cylinder provided a tactile marker of the 100 mL level for students with BLV. By inserting a disposable pipet so that its tip was positioned at the same level as the top edge of the tape, students were able to withdraw oil from the cylinder until a volume of 100 mL remained. This method allowed them to measure the 100 mL volume of vegetable oil accurately. The vegetable oil was then added to a separatory funnel, and 15 mL of methanol and 1 mL of 9 M aqueous KOH were added; the mixture was swirled for 10 min and then allowed to rest and separate for another 15 min. Next, the beaker used for collecting the separated mixture was weighed and the mass recorded. A conductivity probe, which used the same control box as the SALS photoconductivity probe, was then placed inside the separatory funnel with the tip of the probe near the valve (Figure 1), and the SALS was set to a constant pitch. The contents of the funnel were allowed to drain into the collection beaker until the pitch changed, indicating that the conductivity changed as the interface between the aqueous and organic layers passed the tip of the sensor; the valve was then immediately closed by the student. Another beaker was then placed under the funnel to collect the biodiesel product. The contents of the first beaker were discarded and the collected biodiesel from the second beaker was poured back into the funnel. Distilled water, 10 mL, was added and mixed to wash the sample, and the solution was allowed to rest for another 15 min.

Figure 1. Teamwork is important as three students work with their mentor to detect the point at which the aqueous–organic meniscus passes the tip of the conductivity probe in the biodiesel experiment.

The product was again separated using the conductivity probe; the waste was collected and discarded, and the biodiesel was collected. The final volume was weighed, and, using the density of biodiesel (0.88 g/mL), its volume was determined and compared to the original volume of vegetable oil *(15)*.

Condensation Reactions and the Formation of an Ester

In the condensation experiment, students reacted alcohols and acids to learn about esters, the compounds responsible for some of the flavors and smells in perfumes and foods (wintergreen, banana, and orange). The students first prepared a hot-water bath using a hot plate (rather than a Bunsen burner), heating 50 mL of tap water in a 100 mL beaker to a point above 56 °C, using JAWS and Logger Pro with the Vernier temperature probe to track the temperature change. Next, a notched syringe calibrated and Braille-labeled to the required volume was used to add 2 mL of methanol to a test tube, followed by 0.4 g salicylic acid, and 0.4 mL of concentrated sulfuric acid. During this process, the students noted the odors of the reactants. Once all the ingredients were added, the test tube was suspended in the hot-water bath using a ring stand and a test tube clamp. An initial SALS pitch was recorded, and the contents were heated until they reached a constant temperature. At this point, a final SALS pitch was recorded, and the contents were kept at this temperature for 5 min. During this time, the students observed and recorded any new odors; in the event that they smelled nothing, they were instructed on how to safely remove the tube from the water bath and waft the gas above the reaction solution. All smells were recorded and compared to the observations of other students. In a second experiment, 2 mL pentyl alcohol, 2 mL glacial acetic acid, and 0.2 mL concentrated sulfuric acid were used, and in a third experiment 2 mL octyl alcohol, 2 mL glacial acetic acid, and 0.2 concentrated sulfuric acid were used. In each case, the students noted and recorded all odors. Upon completion of the activity, they safely disposed of all chemicals and returned all materials to the serving trays *(13–15)*.

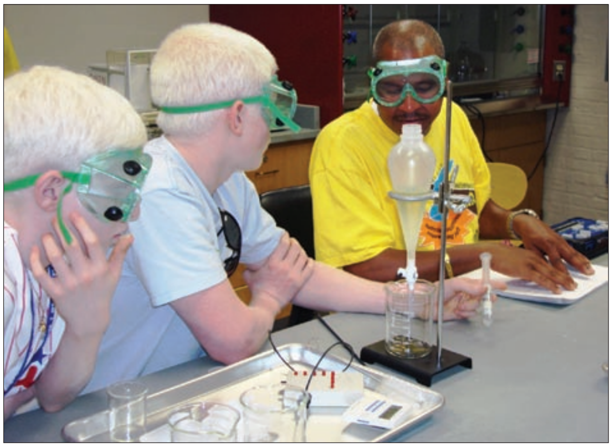

Figure 2. Two students prepare for the biodiesel experiment as their mentor discusses the procedure, reading from a Braille laboratory manual.

Summary

Over the course of the 2007 NFB Youth Slam, the 50 students who participated in the chemistry activities performed hands-on chemistry experiments that they would likely not have had the opportunity to try in most mainstream schools. Students were frequently enthusiastic during post-experiment group discussions, oftentimes going beyond the immediate scope of the curriculum. Students noticed the strong vapors of glacial acetic acid in the Condensation Reactions activity; this prompted a discussion about different proportions of acids and bases and how adjusting these could create different odors, and the widespread use of such formulations in pre-packaged foods, colognes, and perfumes. After the Energy experiment, students directed the discussion toward the environmental ramifications of energy use and how waste affects not only the earth, but our economy.

The students were also exposed to peer modeling, which has been shown to increase self-efficacy, especially in the context of a group project or effort *(16)*. As students observed peers performing a task, they seemed to feel that they were able to perform at the same level. During these group exercises, students wanted to try several different roles within each activity. As illustrated in Figure 1, all three students actively performed the biodiesel separation task at once while guided by their mentor.

The Youth Slam also demonstrated a key benefit of recruiting people with disabilities into the STEM professions. Day-to-day life presents many obstacles to people who are BLV. Consequently, many of these people develop well-honed problem-solving skills to adapt to everyday life *(17)*. Constant learning and continual reassessment of current knowledge is crucial to this form of problem solving, as it is in working within the STEM fields. The mentors of the Youth Slam Chemistry Track displayed this adaptability and willingness to learn in abundance. While the expert mentors were working professionals in the STEM fields, few of the individual mentors were trained scientists (Figure 2). Non-science teachers and college undergraduates, human services workers, and people working in the business fields formed the main body of mentors, and demonstrated to the students their ability to learn outside of their professions well enough to teach others. Providing more hands-on experiences such as the 2007 NFB Youth Slam may help students who are BLV realize they can actively participate in laboratory experiences and may further encourage them to consider career paths in the (STEM) professions.

The tools and teaching techniques demonstrated at the 2007 Youth Slam are currently being implemented into other science curricula, both in mainstream science classes at schools participating in the ILAB project and at non-participating schools. Feedback from teachers and students will lead to further refinements. A new set of science activities will be implemented at the next NFB Youth Slam, to be held on the University of Maryland College Park campus in July 2009.

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