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Using Commercially Available Techniques To Make Organic Chemistry Representations Tactile and More Accessible to Students with Blindness or Low Vision

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ABSTRACT: Organic chemistry courses can present major obstacles to access for students with blindness or low vision (BLV). In recent years, efforts have been made to represent organic chemistry concepts in tactile forms for blind students. These methodologies are described in this manuscript. Further work being done at Illinois State University is also described that allows a student with BLV to independently make properly Braille labeled structures from the organic chemistry online database via ChemDraw.

KEYWORDS: *Second-Year Undergraduate, Organic Chemistry, Hands-On Learning/Manipulatives, Student-Centered Learning, Molecular Recognition*

SOLUTIONS IN THE LITERATURE FOR REPRESENTING ORGANIC STRUCTURES TACTILELY

Organic chemistry historically is one of the most visual branches of chemistry. It requires the 2-dimensional and 3-dimensional representation of molecular structures. Students are evaluated on their ability to produce, interpret, and manipulate these structures. It is these visual representations that have proven challenging for students with blindness or low vision (BLV) in their undergraduate academic pursuits. In recent years, a handful of methodologies for representing organic structures have been published. Supalo et al.[3] describes a 2-dimensional felt board that uses a piece of poster board covered with felt. Circle and rectangle cutouts with Velcro on the backs were used to represent carbon atoms and bonds, respectively. Additional circles were created with print and Braille labels to represent specific elements such as oxygen, nitrogen, and sulfur. The student with BLV would demonstrate mechanisms in a step by step process to a teaching assistant, faculty member, or human reader/scribe to reproduce on a homework assignment or test. This process was time-consuming because once the scribe documented the mechanism, it had to be reviewed to match the student with BLV's intentions.[1−3]

Additional work done by Ovadia and Poon describes the use of a thermal paper expansion machine called Tactile Image Enhancer Junior from Repro-Tronics, Inc.[2] This machine can produce a raised line image by means of a special capillary paper onto which an image can be printed directly from a laser or inkjet printer. The image paper can then be placed in the machine. It utilizes a UV lamp that causes a chemical reaction to occur wherever the black ink is located on the image paper thus causing it to form a raised line. This however is not possible for other colored inks. This technology can be used in conjunction with organic chemistry graphics files produced on a computer. This output can then be interpreted by students with BLV in a tactile way. Further, Ovadia and Poon utilized a 3-dimensional organic chemistry model kit they refer to as the orbit molecular building system by Indigo Instruments. They successfully were able to represent single, double, and triple bonded molecules in a 3D model. These models were useful in the mechanistic studies in the first semester organic chemistry course. The student with BLV was given the starting materials and told what reagents were being used. It was then up to the student with BLV to explain what was occurring. Also, the authors used a product known as Wikki Stix. This is a low cost bendable stick similar to yarn that could be placed on a standard piece of paper to represent various organic structures. The Wikki Stix can be shaped and reused several times.

Later work done by Pereira et al. in Portugal developed a text-to-speech software application called NavMol that could give verbal representations of organic structures.[4] This software application is freely available for download on the web.[5] This interface, although very ingenious, needs to be further refined and made to import commonly produced organic chemical structure files produced by ChemDraw from PerkinElmer, and other similar products.

Further work done by Wedler et al. indicated how access to organic chemical structures, although very desirable, is currently not seamlessly available for blind chemistry researchers.[6]

A paper by Harshman, Lowery Bretz, and Yezierski[7] describes the three modalities of chemical concept presentation. These include the written, verbal, and tactile forms of chemical concepts. It is these three modalities Harshman et al. indicate that can be useful to varying degrees to students with BLV. A student with BLV can vary in ability to interpret visual information in a tactile way. Further, whether or not a person with BLV is completely blind or partially sighted can impact their ability to interpret tactile representations of chemical concepts. Additionally whether or not the person with BLV is blind from birth or has lost eyesight later in life can directly impact their tactile graphics interpretations.

In the Harshman et al. paper, the student with BLV indicated difficulty with the interpretation of tactile graphics in a

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classroom setting. Interpreting multiple modes of information in a lecture setting can be limited by divided attention aspects described in the Harshman paper. It is stated by Harshman et al. that divided attention can limit a student with BLV's ability to fully comprehend chemical concepts in a tactile way. Additionally, more time is likely required for full comprehension of the chemical concepts presented in tactile form. Persons with BLV have varying ability to interpret visual information in a tactile way, which can directly impact the success of the interpretation of the tactile representation. Harshman et al. indicated difficulty with frames of reference of visual conceptual information not familiar to their student with BLV, who required additional verbal description of the concepts prior to full comprehension. Once supplementary verbal instruction was used to provide a frame of reference, the visual concepts were comprehended by the student with BLV.

The Harshman et al. paper indicated that additional verbal explanation in addition to a tactile representation could be useful in the full comprehension of the chemical concept. This can further be beneficial in the instruction of organic chemical concepts to a student with BLV. Verbal explanation and how this information is delivered by both instructors and other classmates can directly impact the quality and level of usefulness of tactile representations of organic chemistry concepts.[7]

THREE COMMERCIAL APPROACHES TO PRODUCING BRAILLE-LABELED ORGANIC STRUCTURES

Using Text-to-Speech Output with ChemDraw

In work done as part of an effort by the multi-sensory teacher education research lab at Illinois State University, we researched commercially available ways to produce properly Braille labeled organic chemical structures. The PerkinElmer product known as ChemDraw, version 13.0.0.3015, has the ability to produce properly Braille labeled elements on a graphical output. Images from the online organic chemical structures library can be accessed via text-to-speech (TTS) spoken output. The TTS used in this study is the Window-Eyes text-to-speech screen reader program available from GW Micro.[8] Window-Eyes 8.0 was able to be used to access the online database of organic structures. The control+N key stroke was used to open a text box to type in a common or IUPAC name of an organic structure. The library then placed a molecular structure on the screen. The control+V key stroke was then used to bring up a list of fonts available on the computer. If the computer has Braille translation software installed on it such as the Tiger Software Suite from ViewPlus Technologies, or the Duxbury Braille translation software package available from Duxbury Systems, these fonts will appear in the list of other available fonts. The font we recommend be used is "Braille29."

Creating Organic Structures with Picture in a Flash (PIAF) Technology

Additionally, a Braille labeled organic structure was produced using a mouse. Within ChemDraw, the "online" section from the program menu was selected. From there, "find structure from name at ChemACX.com" was selected and a molecule's name was entered. A molecule appeared on the screen, as seen in the left panel of Figure 1. Next, the font was changed to Braille29, size 28. Once this font had been selected, all of the print letters were replaced with the Braille dot representations.

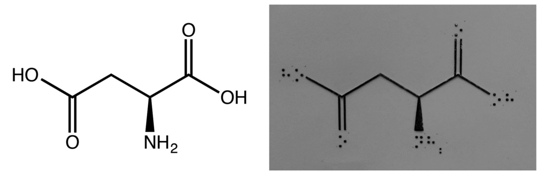

Figure 1. Representations of an organic molecule: (left) molecule produced from ChemDraw; (right) tactile image of aspartic acid with Braille labels produced via Chemdraw and the PIAF machine.

This image can be printed via an inkjet printer onto the piece of PIAF capillary paper. This image is set to dry for 2 to 3 min prior to its being placed ink side up in the PIAF machine. Sometimes the image needs to be put through the PIAF machine twice to ensure proper rising of all dots and lines. The right panel of Figure 1 shows the tactile output of the PIAF machine. The Braille is properly spaced to meet the National Library Service (NLS) Braille dot specifications.[9] Organic chemical mechanisms can also be produced by an instructor or teacher, and proper Braille labeled images can be obtained and produced on PIAF image paper. These images can be 3-hole punched and stored in a notebook for reference.

A Braille embosser is the equivalent of an ink printer with the output simply being Braille instead of print. These devices in recent years have developed the ability to produce raised line images in addition to Braille characters. This technology can utilize electronic files of images and be exported to a Braille embosser in what is commonly referred to as "Graphics Mode." This will provide a student with BLV a raised line drawing of an organic structure. Further, arrows indicating direction of electron flow can also be produced on these raised line drawings.

These images were also found to be producible on the ViewPlus Tiger Braille embosser products. The ChemDraw image can be imported as a .jpeg file into a program called IVEO Creator Pro. The output can be printed to the Tiger embosser and can bypass the need for the PIAF. However, with this method some experimentation with font size and molecule size in ChemDraw is recommended to produce a readable Braille output. ViewPlus also distributes a touch tablet called the IVEO Creator Pro. This tablet can be used to add text labels that can be spoken by the IVEO software. A raised line drawing of an organic chemistry concept can be produced on a Tiger embosser. It can then be placed on the touch tablet. After proper alignment of the image has been achieved on the touch tablet, text tags can be added at key points on the tactile graphic. This will allow a student with BLV to have verbal prompts be spoken by the computer once the text labels have been added by a teacher. Having additional spoken information about a key point on a graphic can help to fill in the gaps left by a limited number of Braille characters being placed on a graphic for a lack of space.

Producing Three-Dimensional Organic Structures with Draftsman and Low-Tech Solutions

Another product available from the American Printing House for the Blind (APH) is referred to as the Draftsman.[10] This is a board that has been equipped with a rubberlike surface. A sheet of plastic paper is placed on the rubber surface. A stylus that is included with the Draftsman kit is then used to draw a raised line image in real time from left to right. The Draftsman produces a visual line, as seen in Figure 2, so that both a blind student and sighted instructor can interact with the device at

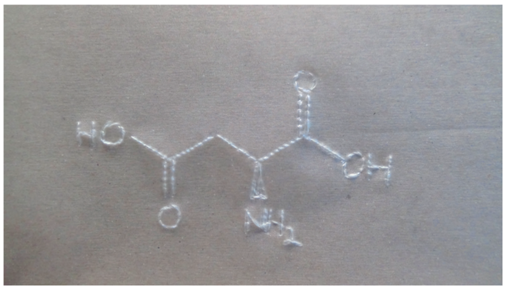

Figure 2. Hand-drawn tactile image of an organic molecule, produced via a Draftsman device.

the same time. The Draftsman has been found to be very useful in tutorial sessions such as those in a professor's office hours. It has also been found to be useful when used by a student with BLV sitting next to a sighted peer in lecture settings. The sighted student can be asked to draw all visual graphics the faculty member uses in lecture. This image can be passed to the student with BLV to read. Sometimes multiple Draftsman devices can be used by this pair of persons if the large number of graphics demands it. The Draftsman can also be used by instructors just prior to lecture to make on the fly raised line drawings of any graphical information they will be lecturing on in that day's class. A vertical line labeling system in the upper right corner of the image page can be developed where 1 vertical line can represent figure 1, two vertical lines can be figure 2, and so on. Of course, if you exceed 5 or 6 images, another labeling convention should be devised between student and instructor. This labeling system should be consistent throughout the course for reference. The student with BLV will be likely using another note taking method such as an electronic note taking device. Within their notes, they can make specific reference to graphics produced by the instructor. It is imperative that the instructor make verbal reference to each figure they are discussing with the rest of the class. This will tell the student with BLV specifically what image to be feeling at the time of the discussion. These images should be dated and filed in a 3-ring notebook for reference.

Another low tech solution for the production of organic structures is to employ a sighted student such as an art major to hand draw organic chemical structures on Braille paper from a textbook. These images should be drawn to be a larger size so as to fit on a standard 11 by 11.5 in. sheet of Braille paper. These images should also label the corresponding figure number from the textbook or handout. The student with BLV and the sighted student can then meet to utilize a device known as a Perkins Braille writer to, under the sighted student's direction, put Braille labels directly on the hand drawn page. A hot glue gun commonly available from an arts and crafts store can then be used to put raised lines over the drawn lines. Once the ink has hardened, you now have obtained a properly Braille labeled raised line drawing of an organic chemical structure. These images can be produced by chapter in the case of a textbook, or can be produced by lecture in the case of lecture notes. These images should be put in order of presentation and placed in a Braille labeled 3-ring folder for reference. Although this method requires extensive use of a sighted student that likes to draw, it is one of the lowest cost ways to get organic and other tactile images produced in a short turnaround time.

CONCLUSIONS

Although the above-described solutions do not represent the end-all, one ideal way to produce organic chemical structures, they do represent a hodgepodge set of techniques that can be used to make organic chemical concepts more accessible to the blind. Access technologies can be used in ways other than initially intended and made to access scientific concepts such as those in organic chemistry. It is up to students with BLV, the creativity of instructors, and others to develop new innovative ways to access science.

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Notes

The authors declare no competing financial interest.

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