JOURNAL OF CHEMICAL EDUCATION
Communication
pubs.acs.org/jchemeduc

ConfChem Conference on Interactive Visualizations for Chemistry Teaching and Learning: Concerns Regarding Accessible Interfaces for Students Who Are Blind or Have Low Vision

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Supporting Information

ABSTRACT: This communication summarizes one of the invited papers to the Interactive Visualizations for Chemistry Teaching and Learning ACS CHED Committee on Computers in Chemical Education online ConfChem held May 8–June 4, 2015. It focuses on concerns of the current societal paradigm as it pertains to virtual simulations and visual animations today, and addresses matters pertaining to the usability of such constructs by students who are blind or visually impaired (BVI). Further, it addresses concerns with the importance of providing equal access to visual information in the teaching of chemistry concepts and comments on the dynamic nature of the teaching profession.

KEYWORDS: *High School/Introductory Chemistry, First-year Undergraduate/General, Curriculum, History/Philosophy, Computer-Based Learning, Internet/Web-Based Learning, Multimedia-Based Learning, Student-Centered Learning, Professional Development*

This paper was discussed May 29–June 4, 2015, during the spring 2015 ConfChem online conference, Interactive Visualizations for Chemistry Teaching and Learning. (See the Supporting Information.) This conference was hosted by the ACS DivCHED Committee on Computers in Chemical Education (CCCE).[1] The teaching of chemistry has always been a dynamic art for chemistry teachers, with the arrival of new innovations shifting and raising the metaphorical bar of expectation for pedagogy in chemistry. Examples of such innovation in recent decades pertain to the rapid integration of technology, including computer-aided scientific data collection and video clips of demonstrations that are difficult or impossible to conduct.

EDUCATIONAL TECHNOLOGY CAN MARGINALIZE SOME LEARNERS

With policies on 21st century teaching-learning environments mandating the use of technology in the classroom, today's educational landscape is undergoing a sea-change. The education profession is rapidly adopting new educational technologies to be on the cutting-edge of pedagogy. However, this race can marginalize the population of students with disabilities, if accessibility and ease of use of said technologies have not been consciously considered in the adoption decision-making process. This marginalization further compounds the problem of significant underrepresentation of students with disabilities in the Science, Technology, Engineering, and Mathematics (STEM) subject areas.[2−4]

One such innovation, seen in recent years, is the advent of virtual simulations to aid in the teaching and learning of chemical concepts.[5−7] Unfortunately, as with many new educational technologies, many virtual simulations are inaccessible to the disabled community. Contrast this with the Council of Exceptional Children (CEC) "promoting meaningful and inclusive participation of individuals with exceptionalities in their schools and communities",[8] as published in their Special Education Professional Ethical Principles standards. This refers to the promotion of a mindset that education should be inclusive for all learners, not just those with exceptionalities. This standard serves as a pillar of praxis for educators and software developers when designing educational applications such as virtual simulations of scientific concepts.

While the access technology (AT) industry has been a responsive force to the technological needs of the disabled for decades,[9] limited collaboration exists today between AT developers and science education technology platforms. This anemic industrial partnership, along with significant underrepresentation of the disabled in STEM courses, impacts developer decisions to build accessible virtual simulations. It is well documented, in the AT industry, that retrofitting a software platform is much harder than making it accessible at the inception of idea.[10] If software developers abide by the most commonly used access guidelines today called Microsoft Active Accessibility (MSAA) conventions in their source code, this would lead to significantly increased accessibility for students with disabilities.[11]

OVERVIEW OF DISCUSSION BY CONFERENCE PARTICIPANTS

A number of comments describing the importance of students with BVI were mentioned in this discussion. One participant stated that students with disabilities tend to be very knowledgeable about their specific needs. Students with BVI can impact instructors' teaching styles to make them more

Received: July 20, 2015
Revised: March 31, 2016

DOI: 10.1021/acs.jchemed.5b00603
J. Chem. Educ. XXXX, XXX, XXX−XXX

multisensory for all learners. Specifically, one comment referred to a male student who was color-blind, and how that individual overcame this limitation by comparing various shades of gray when specific objects were placed side-by-side. The learner's adaptation through a creative and accurate use of comparison was found to be a valuable strength by the instructor of that chemistry course. Another comment indicated specific struggles of color-blind learners with acid−base titrations. The traditional method of visually identifying the end-point of titration presented challenges. These challenges were addressed at another institution that used a digital meter to track specific measurements of the titration, a necessary adaptation for this student to achieve success. This is an illustration of the diversity of accommodations, which can range from low to high-tech solutions involving specific pieces of technology. Both approaches are valuable for students with disabilities in the chemistry laboratory. In addition, students with disabilities can motivate teachers to evaluate how they present their material. This reflective practice may lead to enhancements in visual and other course materials that may be good for all students. Open dialogue between teacher and student can be a valuable experience for both persons in the teacher/student relationship.[3,12]

Multisensory presentations of general chemistry content are valuable for all learners, as illustrated by the use of manipulatives such as molecular model kits in teaching molecular geometries. Visual illustrations for expansion and contraction of gases using balloons engage both sighted and blind students.[13,14] Depending on the gas being formed, the balloon may be held by a blind student to obtain a qualitative representation of the magnitude of the evolution of gas. Hardcopy raised-line drawings of graphical representations that are made available to the blind student at the same time as in-class drawings delivered to their sighted peers can greatly enhance a blind student's ability to comprehend the visual information under discussion.[15] There are many ways to illustrate chemistry concepts: it is up to the teacher to determine ways of multisensory presentation. A teacher used to traditional approaches they have adopted over the life of their teaching career may find it challenging to shift to alternative approaches to teaching chemical concepts in their practice. A teacher willing to innovate their methodologies can enhance the learning process for all their students.

■ ACCESSIBILITY CONCERNS WITH CURRENT CHEMISTRY SIMULATIONS

The following examples are meant to serve as illustrative examples and not intended to be a full representation of all chemistry simulations currently available. It is the author's assertion that the access concerns discussed here are common throughout numerous specific examples; however, not all simulations have been evaluated for accessibility.

Numerous chemistry simulations have been designed by phET at the University of Colorado, Boulder in recent years. These are well-designed and have been demonstrated to contribute to student learning. Some examples of simulations are titled Molecule Polarity and Beer's Law Lab.[5] The molecular polarity simulation requires the use of a mouse to rotate atoms and molecules on a computer screen to study electronegativity. This control allows a user to view and draw connections to the corresponding changes illustrated by an on-screen arrow representing the dipole moment and partial charges and covalent versus ionic bonds. The simulation also allows a user to activate and deactivate a virtual magnetic field to see how it affects the molecule's polarity. However, since this feedback is provided solely through visual representation, with no text-based descriptions of the visual information, there are limitations to what a visually impaired user can learn from this experience. This simulation has three different tabs that illustrate molecular interactions as they pertain to polarity and electronegativity. The feedback that students receive is primarily visual in nature. Additional accessibility features factored in to both the on-screen navigation and control of the experimental variables can render the experience with this simulation more efficacious for visually impaired students.

It also features a Beer's law activity that allows variations in solution concentration to be investigated. There is a concentration tab that allows a student to investigate the effects of dilution and evaporation. Under the concentration tab, students engage in an activity that varies the concentration of different solutions. Students can add solute from an onscreen saltshaker or via a visual representation of a dropper. The effects of adding solute and water to the solution are represented through onscreen color changes. Each action causes a color change illustrated by intensity. The moveable probe allows a student to compare quantitative changes based on the specific question the student chooses to investigate. Solids form at the bottom of the onscreen beaker when the student passes the saturation point. Text-based numerical and visual descriptors can assist a student with a visual impairment to comprehend the visual concepts being illustrated.

The Beer's Law tab allows a student to use an onscreen beam of light to observe absorbance based on concentration variations. The onscreen controls need to be text-to-speech accessible via appropriate alt text tagging and other identifiable conventions. The visual qualitative information being communicated should be described with text-based descriptions that are dynamic in nature. This can make this simulation more efficacious for visually impaired students.

In another paper by Clark, he describes a phET simulation called The Models of the Hydrogen Atom. The graphical representations featured here can be represented for students with visual impairments via tactile graphics.[16] Although this is not a dynamic representation equivalent to what the simulation offers nonvisually impaired students, it is the opinion of the author this is the best solution available with current technologies. There can be a delay in production of these graphics that can be reduced to a matter of minutes subject to the availability of tactile graphics production technologies. Numerical values of photon strength and light emissions can be represented with text-based numerical values. Color emission can also be provided via a text descriptor, thus allowing a visually impaired student to make connections between numerical and visual representations. The student can see multiple representations for each of the six models so that students can coordinate between atom animations, electron energy level diagrams, and predicted atomic emission spectrum. These reference materials are used to compare experimental features designed in an onscreen black box experiment. On the basis of the results of the black box experiment, a student can compare the experimental results with those reference data sets. The goal of the experiment is to see which model fits best with the experimental data collected of the models of the hydrogen atom simulation. This was developed to assist students in the visualization process.

DOI: 10.1021/acs.jchemed.5b00603

The simulation should contain Microsoft standard keystroke navigation, which does not currently appear to be available. Text-to-speech interface requires keystroke navigation that will allow a visually impaired student to control the simulation. Without this basic feature, no direct independent interaction with the simulation is technologically possible.

The simulations described here are very well designed pedagogically and have been proven to be valuable for the overwhelming majority of users. This narrative is intended to describe how these and other simulations designers can make their simulations more useable by students with visual impairments. Often the needs of the few are overlooked for the needs of the many.

■ ACCESS TECHNOLOGY SOLUTIONS

Simulation developers are encouraged to consider accessibility while developing their interfaces. The new features incorporated into simulation platforms can and will create multimodal channels of feedback that will enhance learning for all students. This complementary approach to innovation will yield better products for all involved.

Existing AT solutions for BVI learners that have been around for decades include the use of text-to-speech (TTS) on either a Windows, Linux, or Macintosh platform, and interfacing refreshable Braille displays with computers to provide a Braille character representation of text-based content.[3,9,17,18] Low-vision students use screen magnification software in conjunction with hand-held and/or camera-interfaced technologies (close circuit televisions or CCTVs) to access print information.[3,9]

Other solutions include printing documents in large font and, for students who read and write Braille, using a Braille embosser in conjunction with Braille translation software to convert documents available in word processor file formats into a Braille Ready Format (BRF) to be embossed into hardcopy Braille. Some Braille embossers also produce raised-line drawings to illustrate two-dimensional mathematical and scientific concepts.[19] A lack of awareness on the part of chemistry educators and software developers, of these and other existing AT which may serve as models for innovation, is a barrier to new access platforms being developed.

The desire and resources to alter this current status quo exists, as exemplified by the case of Apple. Today, the Apple iPhone product is an accessible platform for the BVI community. When first released, prevailing wisdom supposed it impossible for touchscreen technology to be accessible to the BVI population. This mindset drastically changed with Apple's commitment to develop and implement the "Voice Over" TTS interface as a standard feature on all Apple products.[20] This innovative nonvisual access interface uses a voice output, in conjunction with a double tap construct, to allow a person who is blind to navigate the screen without accidentally selecting options. As a result, Apple products were rapidly adopted in the blind community.

It is the hope and expectation that virtual simulations can and will become more accessible to students who are BVI through innovations such as multisensory interfaces which use tonality, beeps, and TTS supports with commercially available products such as "Voice Over". The ability to capture a visual image and render it into a tactile graphic or three-dimensional model will also increase access. It is likely these alternative interfaces may require the use of more time for analysis or a less dynamic presentation. Ideally, the priority is to provide access in real-time, but technological limitations may dictate some static presentation.

As technology innovates, so too will access. It is critical that the needs of the perceived few are not discounted in the race to be the first to innovate. To the product developer, designing innovation while maintaining usability by as wide an audience as possible is the desired paradigm.[21] While there will be times when we miss the boat and retrofits will be necessary, it is the open-mindedness to partner with AT companies to make accessibility a norm that is so badly needed.

■ CONCLUSION

Virtual simulations of chemistry concepts are a valuable contribution to student learning. However, to date, the many simulations are not designed to be accessible for students with visual impairments. This gap is a design oversight. The overwhelming majority of students pursuing STEM career paths currently do not have disabilities. However, as more doors of opportunity are opened and more digital platforms of science education are developed, accessibility for all users should be kept in mind to ensure equal opportunities are available for all learners. This will lead to a more diversified STEM workforce that is more welcoming of persons with disabilities.

■ ASSOCIATED CONTENT

Ⓢ Supporting Information

The Supporting Information is available on the ACS Publications website at DOI: 10.1021/acs.jchemed.5b00603.

The ConfChem paper and discussion (PDF)

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Notes

The authors declare no competing financial interest.

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