Title: Technological Challenges to Equal Access of the Virtual Laboratory Experience for the Blind

Author: Cary A. Supalo

Abstract: Too often students with visual impairments are marginalized in the science laboratory classroom thus limiting opportunities to fully access these experiential learning events. This is further illustrated in the total number of Science, Technology, Engineering, and Mathematics (STEM) professionals with visual impairments. As virtual experiences, with their high reliance on visual interfaces, become more mainstream in the science classroom both at the secondary and post-secondary levels, access is limited even further. Multi-sensory outputs are necessary in order for these virtual interfaces to have higher cognitive and pedagogical value. It is hypothesized that multi-sensory presentation can enhance learning for all students. Students with visual impairments frequently use what are referred to as text-to-speech and/or large print interfaces. Innovation lies in the challenges in the non-visual access provided by text-to-speech interfaces. Properly text tagged buttons and other qualitative tone outputs can drastically enhance the quality of the experience for the visually impaired user. In these times of educational budget cuts, having accessible virtual learning experiences for students with visual impairments are beneficial to all learners and provide a cost-effective approach to fostering continued interest in STEM education.

Challenges of Blind and Low Vision Students in Science Education

Students who are blind or have low vision (BLV) are faced with many challenges in science education. These challenges typically are associated with access to the printed word. [1] Additionally, experiential components of science classes can also be challenging to access.[2] The overwhelming under representation of persons who have BLV in the Science, Technology, Engineering, and Mathematics (STEM) workforce has caused many to ask the question, "Why aren't there more persons with BLV participating in these very lucrative professions?"[3] Some attribute it to lack of access technology. Others attribute it to a lack of equal opportunity. Still others attribute it to misconceptions of the physical capabilities of persons with BLV in everyday life.

There is no one clear explanation as to why this under representation is occurring. However, it is safe to say that hands-on science learning experiences has been well documented to be valuable in maintaining student interest in STEM education among the non-visually impaired community.[4] Later work done by Supalo has demonstrated that learning trends among sighted non-disabled students are paralleled by students who have BLV."

Students with BLV must problem solve on a daily basis to overcome their physical challenge. It is this life long experience of problem solving that has made it a common sense solution to work with this population and to give them STEM related questions to answer.[5] This lifelong commitment to problem solving can translate into dedication to professions that recognize this skill. There is a significant unemployment rate among persons who are blind or have low vision. According to statistics kept by the American Foundation For the Blind, 55 to 60% of blind Americans in 2015 are unemployed.[6] This statistic applies to the entire workforce in the United States. It can be further asserted that this percentage is even greater in the STEM professions.

One major misconception regarding persons with BLV in the STEM workforce has to do with laboratory safety. It has been assumed that since persons with BLV have a limitation seeing things visually that the science laboratory would present numerous safety hazards.[2] As a result, it would not make sense to employ persons with BLV to work in a science laboratory. In a paper by Swanson and Steere Et Al, found that persons with disabilities were no more likely or less likely to suffer injury while on the job as compared to their able body counterparts.[7] It is this detailed study that further reinforces the notion that persons with disabilities out of necessity must pay extra attention to their surroundings and are more aware of any potential hazards and thus can minimize any possible injury potential.

Importance of Virtual Simulations in Science Education

Science education traditionally has been on the cutting edge of educational learning experiences for all learners. This innate ability to be at the forefront of educational teaching evolves from the nature of science. Science educators are always learning for new ways to communicate science concepts to their students. Thanks to the evolution of educational technologies, personal computers were introduced into the classroom along with multi-media audio/video presentations. This was later complimented with the first generation of virtual science applications usually in the form of software applications conducted in classroom computer laboratories.

As these virtual activities became more dynamic and more interactive, science educators started the shift to replace hands-on physical activities with more inexpensive virtual experiences. It is this trend that started saving schools science education dollars.

Around this time, computer assisted laboratory experimentation started to be very common in the science laboratory classroom. This illustration of computer assisted data collection clearly illustrates how hands-on science learning experience can be enhanced by the computer and thus more quantitative data collection is now possible.[8] This enhanced the data analysis experience for the learner and thus further enhanced the science learning experience.

In recent years, changes in lecture presentations have undergone significant evolution. The concept of the flipped classroom is one illustration. Science educators, with the commonly available video recording equipment on tablet computers and personal cell phone technologies has made it easy for science teachers to conduct detailed lessons in advance of class time.[9] [10] The advent of the on-line course management system has allowed educators the ability to make this video content available to students in advance of class. It makes it possible for students to view lessons and try homework prior to coming to school. This allows the teacher to use class time as an opportunity for the students to try more advanced problems and be provided more individualized tutorial support. The use of the on-line course management system has also made it possible for school lessons to be conducted even on days when school closings would traditionally occur. All of this technology evolution is based on the assumption that the students and their families have access to the Internet and computer technologies. Without these resources, none of these benefits would be possible.

In more recent times, science educators have seen the power of virtual simulations as nice compliments to both laboratory and lecture presentations. It is this enhancement to content presentation that has made educators more dependent on the visual image being communicated and less on the verbal explanation of the concepts being discussed. This shift in instruction may be due to the virtual simulations evolving to be so detailed and elaborate that it causes the educator to really become more dependent on the adage, "A picture is worth a thousand words." It is this adage that is difficult to quantify in instruction. [11] [12] [13]

Challenges to Access for the Blind to Virtual Science Simulations

Visual science content has become more apparent in recent years. This has been further illustrated in textbook presentations being supplemented by links and course cd tutorials and on-line web support to electronic or e-textbooks. This in addition to audio and video content on-line is further making the teaching of science more visual. This shift in visual instruction is reinforced by multi-media presentations designed to teach technical science concepts in more of a visual manner. This has been compounded by the need to shift education from a more informative conduit to that of a more entertainment based conduit. This has become a mandate as a result of the societal adoption of electronic gaming and social media thus making students more accessible to on-line information. The availability of technology in the classroom can distract student's attention from their studies to other non-study related matters. Computers may in some way have become more of a distraction rather than a compliment to science learning. This can be illustrated through social media sites being readily available in class. This causes students to be distracted by what is going on in the world rather than what is going on in class. Thus, the dependence on the entertainment based model of science instruction.

The visual nature of science as a whole makes virtual simulations a logical tool in science education. However, this visual nature has created unforeseen barriers to access to visual content by students who are dependent on other more auditory and tactile based interfaces i.e. students who are blind or visually impaired. With their innate challenges to accessing visual content, material that is heavily dynamic, ally graphical and illustrative has introduced an entire new form of access challenges. The new access challenges created by advanced visual illustrations and animations to complete virtual science learning interfaces have unintentionally created barriers to access. The amount of electronic content both in the form of e-books and in on-line content has created a large demand by the blind for access to this added content. Never before has so much visual content been available in any time in human history.

Due to the overwhelming amounts of non-technical materials now available has driven the desire for more access to technical content.

Currently an overwhelming number of virtual science simulations are visual animations of specific science concepts. Some of which are dynamic in the sense that students can control and change parameters to investigate what might happen in different scenarios. These simulations can incorporate audio interfaces, but the large majority currently do not. As a result, this has limited the amount of benefit that is possible to students who are blind or visually impaired from this visual content. It is this current lack of access that has created an entirely new dynamic of limited access in science education.

Additionally, school administrators that shift lower demand science courses such as advanced placement courses from the physical platform to virtual may limit access by students who are blind or visually impaired to a comparable science learning experience to their non-visually impaired counterparts. It is this unwillingness to commit a science faculty member to teach such advanced topics in the advanced placement areas that has become more common in recent years. As a result, this has made science laboratory experiences more difficult to access. Although sighted students have experienced little change as a result of this shift in technology interface, students who are BLV have experienced a radical change. It is this shift in platform that may adversely affect performance on advanced placement assessments thus limiting the number of awarded advanced placement credit to students with BLV.

It is this limited access that is further compounded by the science education industry's unwillingness to commit to accessibility standards in software based products that are commercially or in open source form and available to schools around the world. There is a feeling that accessibility in science education is currently not a priority to a large majority of manufacturers, software, textbook, and other content publishers. The resistance to the incorporation of accessibility attributes is not likely these manufacturers of such products and services intentionally wish to leave out the blind and disabled from the science educational learning experience, but simply an unawareness as to the benefits to a more inclusive science learning experience for all students. In other words, the full integration of the blind into science learning experiences can enhance the experience for all learners. This can be measured through additional awareness and attention to detail that is required by students in peer learning situations to keep in mind when sharing ideas and explanations. It is this among many other reasons why it is valuable for all learners to be included in the science learning experience.

Once the science education industry decides to make a strong commitment to the full inclusion of the disabled into the science education learning environment will be the time when we as science teachers can reap the benefits of our labors.

Importance of Multi-Sensory Interfaces for Virtual Simulations

Multi-sensory science learning is becoming more paramount as a result of the educational requirement that students receive more dynamic and engaging learning experiences. In an attempt to go beyond the hands-on learning experience, science faculty commonly incorporate live demonstrations whenever possible to keep students engaged. The nature of a live demonstration creates a multi-sensory learning experience by providing visual, audio, and in many cases an olfactory and in some cases a sense of touch to the science being illustrated.[14] [15] Anything from the lighting of a hydrogen filled balloon explosion to some complex illustrative color change sequence can keep students engaged in the learning process. Students also become more engaged when they feel the content knowledge they are learning about has a direct impact to their daily lives. This can be illustrated through an overwhelming concern for cellular phone technology and activities based on the question: does this extensive use of cellular phones lead to serious forms of cancers? It is this concern for personal safety that causes students to be engaged with content presentation.

Further, multi-sensory science learning also can keep students engaged in content presentation. This is apparent if there is a perceive element of risk to personal safety whether that be to the science teacher and/or to the student or something that has assigned value. This can be illustrated with the live demonstration that requires a science teacher to light a large dollar bill on fire that has been properly dipped in methanol in advance. We as science educators also acknowledge that not all demonstrations work as planned, thus on occasion, the dollar bill is lost as a result of preparation error. It is this risk of loss of resource that can engage students.

Live demonstrations along with hands-on science laboratory experiences can increase student interest in the science concept being investigated while reinforcing the student's perception they can conduct scientific research. It is this reinforcement of science research that is extremely valuable in a student's desire to continue down the path towards a STEM career.

Multi-sensory science learning experiences are equally valuable for students who are blind or visually impaired. The ability for a student with BLV to directly experience scientific phenomenon as compared to simply looking at video and photographic illustrations of science concepts makes the learning more tangible.

In addition, direct hands-on learning experiences where the student with BLV is making significant intellectual contributions to laboratory group discussions further can reinforce increased interest in science. Through the advent of new access technologies that make direct hands-on science data collection possible by the blind has revolutionized how the blind can more fully participate in the science laboratory. This has been accomplished through text-to-speech enabled science data loggers now commercially available. This has been achieved by means of portable handheld technologies and/or text-to-speech enabled scientific data collection software platforms.[16] [17] It is this more equal access to quantifiable scientific data collection that has changed how and what students who are blind or visually impaired can contribute intellectually. Further, it is this text-to-speech and otherwise audible interfaces now available that have made science learning more multi-sensory for all learners.[18]

For example, the use of sonification of Cartesian graph data can draw extra attention to non-visually impaired students to mentally visualize graphical data in both a visual and audio form. Sonification output utilizes a tone change to represent the slope of a line on a Cartesians graph as one illustrative application. A line with an increasing slope will be represented by an increase in tone. Additionally, a slope with a negative value will be represented by a drop in tone. It is multi-sensory interfaces such as these that are enhancing science learning for all students. Thus, this further documents how multi-sensory science learning can positively impact student learning and thus lead to increased academic achievement. It is these and new cutting edge technologies soon to be available to the science education community that are ensuring the science education profession is dynamic and meeting the needs of science students.

Summary

Virtual simulations of science concepts illustrate how this is simply a stepping stone on the path towards a full inclusive science learning experience for all learners. Once virtual science simulations become more multi-sensory in nature they will become more accessible to all students. Through the ability to customize how much multi-sensory capabilities are available to the individual students will allow them to control what sensory outputs are most desirable. This is analogous to operating systems now available on personal computers. Users have the ability to incorporate non-verbal forms of communication with their computers in the form of customizable chimes, tones, and other audio patterns to carry specific meanings. These meanings can illustrate arrival of a new e-mail message, low battery alarm, to the availability of a new software update. It is these non-verbal and non-text based forms of communication that can empower the computer user to not be distracted by other stimuli in their local environment. However, these tones can call attention to critical pieces of information on a just in time basis. It is this available form of information that can directly positively impact productivity of the computer user.

This analogy can further be extended to the virtual science simulation. Providing customizable outputs can minimize possible cognitive overload that may be experienced by some learners as a result of their individualized learning needs.

Once virtual science simulations have been fully developed and customizable by both the science educator and the student, then this may open doors of new technological breakthroughs in more multi-sensory interface technologies. This may involve the use of haptics interfaces and three-dimensional printing technologies being improved to the point where physical objects can be produced in a similar fashion to two dimensional printing available now. As technology evolves on an exponential basis, this leads science educators at the forefront to education and what is possible in the classroom. Through our leadership the science education profession is truly serving as a trail blazer phenomenon to the classroom of tomorrow.

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