ABSTRACT

A Blind Student's Success: A Case Study Examining the Strategies of Teaching STEM Courses to the Blind

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Blind or low vision (BLV) individuals have been traditionally discouraged from pursuing a degree in the STEM field. Although steps have been taken to reverse this mindset, the resources available to aid educators in teaching BLV individuals are still lacking at the university level. The aim of this case study is twofold. First, to prove that a BLV student can be successful in challenging STEM courses. Second, to examine the effective strategies and technologies that educators can utilize to teach BLV students. A BLV sophomore student enrolled in both analytical and organic chemistry was interviewed over the course of two semesters to provide insights on the current accessibilities available in pursuing a STEM degree. The rationale behind the use of tactile representations is discussed as well as the accessibilities in the laboratory environment. The findings of this study are used as a point of reference for faculty, student assistants, and future educators paving the way for BLV individuals in the STEM field.

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A Blind Student’s Success: A Case Study Examining the Strategies of Teaching STEM Courses to the Blind

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CHAPTER ONE

Introduction

People who are blind or low vision (BLV) have largely been discouraged from pursuing careers in science, technology, engineering, and mathematics (STEM). Many believe that the visual and mental barriers in these fields are too great for BLV individuals to overcome. Although it is true that barriers exist, they are not so impossible to break past as some may think. In fact, the greatest barrier is created by this mindset itself: the limiting belief that success in the STEM field cannot be achieved by BLV individuals. Although this thinking is beginning to shift, the lack of resources available to educators as well as inadequate preparation among educators continues to dissuade BLV individuals from considering a STEM career.[1]

In recent years, efforts have been made to improve the educational system for BLV individuals in STEM, however the current awareness and accessibilities do not yet suffice to adequately support this demographic.[2] A survey conducted by Cornell University in 2017 found that among visually disabled people ages 21-64, 31.9% had a high school diploma, 30.7% had some college experience or an associate's degree, and 15.9% had a bachelor's degree or more.[3] With a minority of BLV individuals obtaining a bachelor's degree, the amount of individuals earning a degree in the STEM field is even lower. While progress has been made, there remain significant barriers in place that prevent BLV people from pursuing STEM careers.

Current online resources mostly consist of general guides for the education of the blind, such as the American Chemistry Society (ACS) guides or other resources contributed by specific schools for the blind. However, while these guides are helpful, they lack the specificity needed to adapt and successfully teach different STEM courses. An article published in 2013 by Harshman argues that guidelines need to be made for specific chemistry concepts in order to provide detailed instruction for educators to follow while educating BLV students.[4] Harshman hopes to "bridge the gap between overarching ideas about learning as a BLV student to a more in-the-field, observational approach." As of now, general guidelines exist but educators need more course specific knowledge of how to teach BLV students as well as the resources to do it well.

This case study examines the strategies, accessible technologies, and other resources used to successfully teach a BLV student both analytical and organic chemistry at Baylor University, an R1 research institution. Analytical chemistry has a greater mathematical focus and includes material like statistical analysis, titration calculations, and overall instrument understanding. In contrast, organic chemistry is significantly more visual, including a variety of molecular mechanisms, molecule orientation, and reagents to memorize. By studying both of these courses, the BLV perspective can be analyzed through a diverse range of STEM material. The aim of this study is twofold. First, to demonstrate that BLV students can absolutely succeed in the STEM field. Second, to aid educators by describing the methods of education that have proved to be the most useful and effective as well as those found to be unnecessary.

CHAPTER TWO

Materials and Methods

The subject of this case study is sophomore student Noah Cook, a BLV biochemistry student enrolled in both analytical chemistry and organic chemistry courses at Baylor University. The study took place over the spring and fall semesters of 2022, a total of thirty-four weeks. Noah attended lectures and would meet with assistants after class 3-5 times a week for both analytical and organic chemistry. All assistants were STEM majors with no previous experience tutoring a BLV individual. Each assistant had also taken both analytical chemistry and organic chemistry in the past.

Data collection took place in the form of two types of interviews, formal and informal. The informal interviews were casual conversations about the class homework and what study strategies seemed to work the best throughout the semester. These were spontaneous, as new material would arise and troubleshooting would take place. The formal interviews were conducted over the course of two hours and involved outlined questions about Noah's experience. These were done in question-answer format and were primarily for Noah to reflect on his experiences and address what he found to be the best strategies for a BLV student to tackle the two classes. The formal interviews were recorded with the Voice Memos app and transcribed using Otter.ai in order for the qualitative data to be better analyzed.

Background of Participant

Noah was born with glaucoma and became legally blind in the 9th grade, only being able to see minimally out of one eye. His high school years required major adjustments in every area of life. By his senior year, he had lost all vision in both eyes. In an effort to adapt quickly, Noah began experimenting with accessibility technologies and seeking viable strategies himself when teachers and parents simply did not know how to bridge the gaps left by his lack of sight.[5] After attending an Adjustment to Blindness Program in Minnesota, he started his college career at his first university in the fall of 2020.

Figure 1: Participant Noah Cook

Despite the difficulties BLV students face in the STEM field, Noah was determined to pursue a career in STEM since the beginning of his freshman year in high school.[6] Starting as a Nutrition major, he experienced for the first time what being a blind student in a STEM major could be like at a university. He recalled the year he spent at his first university, saying, “[I]t just kind of showed me how bad it actually is, where no one really knows how to accommodate a blind pupil… I wish I had other people helping me out, but I was just figuring things out on my own.”[5] Starting in college, Noah was faced with the lack of accommodations, but also had to work through the transition to online classes marked by the COVID semesters. By the end of this difficult time of transition in his life, he was burnt out and looking for support. It was during this time he reached out to the Texas School of the Blind and was connected with a Dr. Bryan Shaw from Baylor University who was actively working to research BLV student accessibility and educational strategies. Encouraged by the research being conducted by Dr. Shaw, Noah Cook transferred colleges and began his sophomore year at Baylor as a Biochemistry major.

BLV Accessible Technologies

Over the course of the first two semesters, several different types of BLV accessible technologies were implemented. These included general technology that would help any blind individual, as well as tools with more specific tactile function. The VoiceOver Utility available on Mac computers was used throughout both semesters. This screen reader extension converts text to audible speech for the user to hear as they navigate their computer. Noah had previously used this software and was familiar with it. For Windows computers, a similar utility exists called Job Access with Speech (JAWS), however this utility was not used in this study. For any mathematic material, Noah used the ORION TI-84 PLUS talking graphing calculator, which vocalizes all buttons and functions of the calculator.

Figure 2: TI-84 PLUS Calculator

For technologies focused on tactile function, a tactile pad from American Printing House for The Blind was used most often. Using special plastic paper and a stylus, an image can be scratched into the paper by exerting pressure. The indentations made by the stylus can be felt on the surface of the paper, with higher pressures making deeper indentations. A Swell Form Machine was also used to create tactile images. Using the machine specific Swell Touch Paper, an image can be printed onto the paper and then passed through the Swell Form Machine, as shown in figure 3. The machine applies heat, making the ink and paper go through a reaction that causes it to swell up, resulting in an image that can be felt above the plane of the paper.

Figure 3: Swell Form Machine

Several easy-access options were also utilized during the period of this study. The same Esculand Molecular Kit in 3D that is recommended for any organic chemistry student was also found to be useful for Noah. The 3D structures representing atoms have unique numbers of bond attachments that can be felt, allowing BLV students to mentally visualize and build their own molecules. WikkiStixs and hot glue guns were used to create tactile images on pieces of paper. The WikkiStixs are wax sticks that can be bent and shaped to represent molecules and the glue from the hot glue gun can be used by an assistant to create tangible images on paper for BLV students to feel. Using these resources, Noah was able to tangibly feel the concepts discussed in organic chemistry.

CHAPTER THREE

Results and Discussion

Rationale

Any student learning a subject needs to have avenues to input information, process it, and be able to demonstrate the information through output. Inputting information can come from several different sources, for example, reading the textbook and hearing the lecture. These are instances of visual input and audible input. By writing down notes, the student exercises tactile output. For sighted students, visual and audible inputs are the most common.[4] Sighted students view the PowerPoints and listen to the professor at the same time. When these inputs and outputs work in sync, successful learning takes places.

The same can be said for BLV students, the only difference is the source of the inputs. During lectures, Noah could not read the PowerPoints, but would still listen and follow along; this audible input is the same. In order to study outside of class, he used VoiceOver to go through the PowerPoints himself and connect them with what the professor said during lecture, another audible input. Tactile images and objects supplied by assistants were a unique and necessary form of input, essentially allowing Noah to visualize information without actually seeing it. Figure 4 represents the different types of information inputs used in the study. In the following sections, the study strategies of each input are analyzed for their ease and usefulness in mastering analytical and organic chemistry from a BLV perspective.

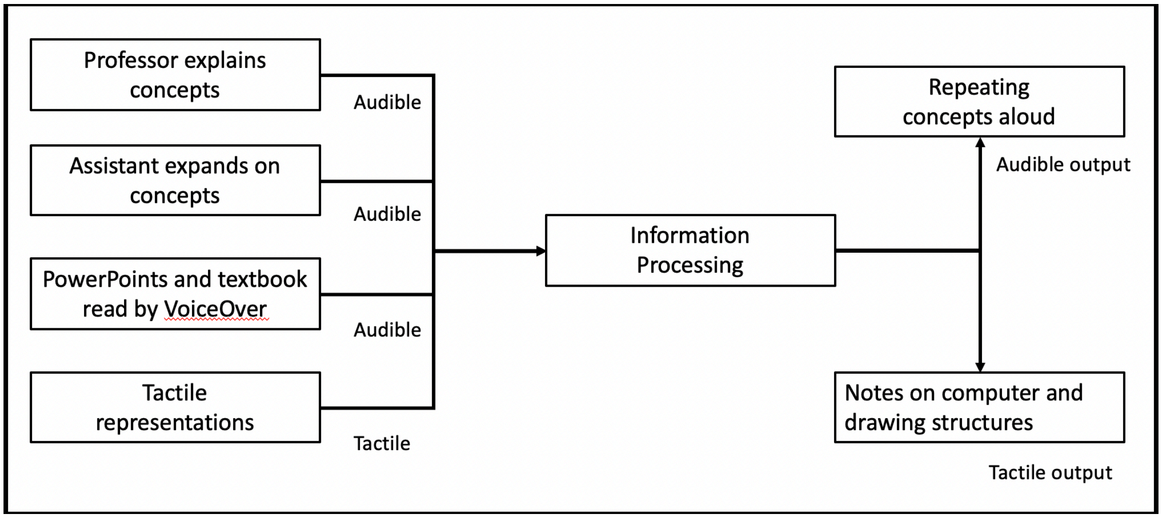

Figure 4: Summary of Noah's Learning Style

Tactile Representations

As the only information input besides auditory, tactile representations are essential and played a major role in this study. There are many instances where tactile images are much easier to understand than simply listening to descriptions.[7] For example, an assistant might spend ten minutes describing a molecule with all of its bonds and geometry, when a tactile image of the molecule's Lewis structure can be understood after a few minutes of engagement. It all connects with the BLV student's ability to visualize the image. In fact, the visual cortex of the brain in BLV individuals is still active and functional despite the loss of sight.[8] When this topic was brought up with Noah during an interview, he said, "I would honestly say I'm a visual learner, even though I can't see… So I feel my environment and that puts a picture in my head."[5] Just like sighted students, BLV students need to be able to visualize relevant material in their classes in order to successfully master it.

During the study, Noah often favored his personal tactile pad for quick sketches of concepts to accompany verbal descriptions. While taking analytical chemistry, this was mainly necessary for graphical information, studying wavelength and frequency, and visualizing instruments such as a Mass Spectrometer. The assistant would sketch out the concept on the tactile pad, which allowed Noah to connect the lecture information to a mental image. This resource was incredibly useful when Noah was having a difficult time understanding a concept as well as when creating simple practice problems. Understandably, the tactile pad did not have a use in the mathematical portions of analytical chemistry but was an excellent aid for any simple visual concepts along the way. For organic chemistry, which is almost all visual science, the tactile board was used daily during tutoring sessions. Since Noah could also use the tactile pad to draw on, it became his main output source for demonstrating mastery of organic chemistry mechanisms. Figure 5 shows Noah drawing out an organic chemistry mechanism with both the Hoffman and Zaitsev products. Noah could verbally explain the reactions, but more importantly, could also draw them out the same way as any sighted student in the class.

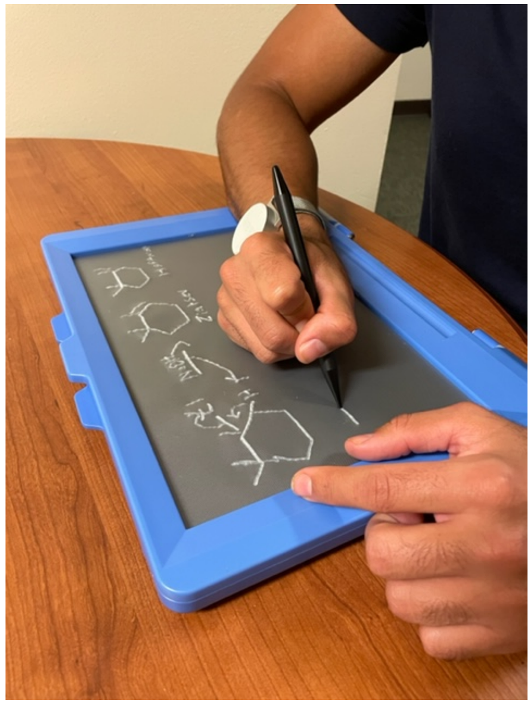

Figure 5: Noah drawing an organic chemistry mechanism on his tactile pad

Nevertheless, the tactile pad also had its disadvantages. Because of its small surface, large or lengthy sketches were difficult to draw. This is coupled with the fact that lines too close together on the paper would become difficult to distinguish. The ACS Guide to Accessibility discourages tactile representations that are too clustered and confusing for BLV students to comprehend.[9] In accordance with this, the tactile board worked best when images were expanded as much as possible. Everything drawn on the tactile board was done by Noah himself or an assistant, so ultimately, the image was only as good as the person drawing could make it.

Whenever the tactile board was not enough to express the detail or entirety of an image, the Swell Form Machine was used. The function of the Swell Form Machine is very similar to the tactile pad. It takes an image and makes it tangible on a paper surface.

The machine's advantages are that it can make more distinguishable lines, and each image can be larger and more precise since images can be copied directly from a PowerPoint or textbook. In fact, Noah began using the Printer-Swell Form Machine combination to select images from his textbook pdf file and print them out without any assistance. This saved a lot of time for when Noah wished to study but an assistant was not available. For organic chemistry, this resource was used often to print out tactile forms of all the chemical mechanisms and representations of electron movement between molecules. The print-outs were kept in filing folders to keep track of during the semester and Noah could pull them out to study at any point. The disadvantages were that the Swell Form Machine is more expensive than a simple tactile pad, and might not be an option for all classes for this reason. In addition, it can take more time to print out an image than to draw it. The most successful way to use the Swell Form Machine was to print out the desired tactile images beforehand so they were ready during the tutoring sessions. An additional challenge that occurred was when the special Swell Touch paper ran out and new shipments took a long time to arrive. During this time, the easy-access tactile resources were utilized instead.

The tactile representations that were the simplest to assemble were created with the hot glue gun, WikkiStix, and the Molecular Kit in 3D. In the absence of the Swell Form Machine, large tactile images were still made using the hot glue gun to trace the images on a piece of paper. Once the glue cooled, Noah could successfully feel the image. The precision of the hot glue images depended on the assistant, but usually sufficed to draw out the organic chemistry molecules overall. The WikkiStix could be used in two ways. First, they were most commonly used to supplement the Swell Form tactile images, as shown in figure 6. By manipulating the wax, arrows can be formed to represent “arrow-pushing” and entire molecules can also be created by using the wax as lines on the paper. Secondly, 3D molecules can be made by sculpting the wax; however, the structural integrity and comprehension of these wax 3D molecules was poor in comparison to other methods. For better construction and visualization of 3D molecules, the Esculand Molecular Kit in 3D was utilized. The molecules constructed from the kit were clearly more accurate and stayed together well during periods of engagement. They were best used when examining molecule orientation and shape. While starting a new concept, Noah found that putting together the key molecules from class and examining them with the mechanism in mind would set the foundation for the new chapter and concepts.

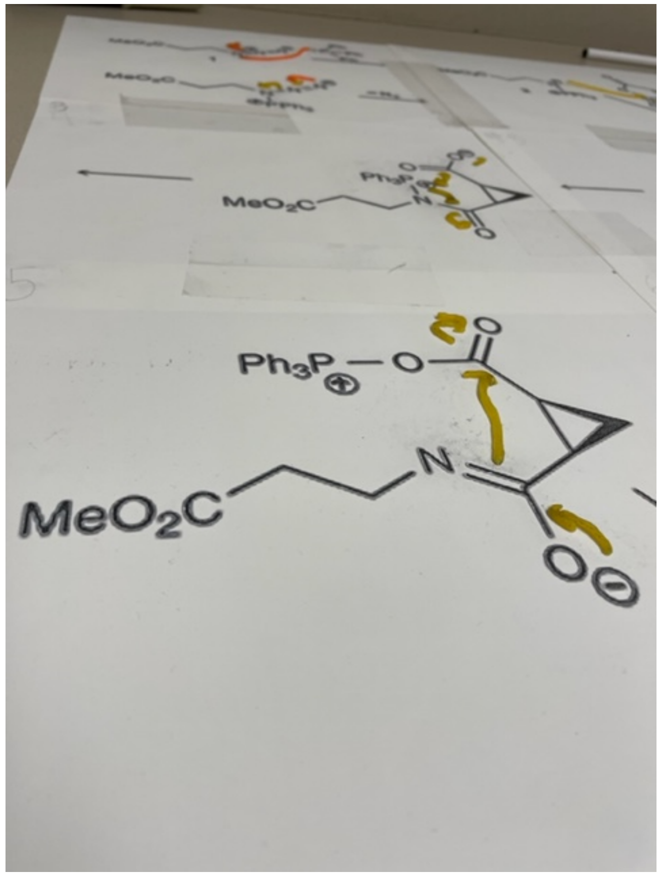

Figure 6: Swell Form paper supplemented with WikkiStix arrows

PowerPoint and Other Computer Resources

Over the course of the study, Noah had several key online resources that he used consistently. These were the textbook pdf file, PowerPoints, and online weekly assignments. Prior to lectures, Noah would access the textbook pdf file and, using VoiceOver, would read the material before class to prepare. Noah stated that this seemly simple task could actually be burdensome since VoiceOver would often relay the text in confusing ways.[5] For example, when reading an equation with variables, unless the letters are capitalized, VoiceOver will call out the series of letters as if they are a word instead of stand-alone letters. Whenever something like this happened, Noah would have to go letter by letter to try to understand what the textbook was saying. He described this as an added puzzle that decreased his efficiency.[5] As for images in the textbook, VoiceOver was not be able to describe those at all. In such cases, Noah would rely on the Swell Form Machine or an assistant's description of the image. The textbook's role was mainly a general introduction to concepts but could not be used on its own to successfully learn new material.

The PowerPoints provided by the professors were an improvement compared to the textbook pdf. Information would be broken up into slides and summarized in more straightforward ways. Noah used them after class to study and would at times go over them with the assistants. For images in the PowerPoints, Alt-Text was used. This technology is accessible within PowerPoint's system and allows assistants to manually write-in descriptions of each image that VoiceOver could then repeat audibly to Noah. Very little effort was needed to do this and it worked extremely well. The drawbacks of PowerPoint were when the professors used many animations in their slides. VoiceOver would describe the animation itself. For example, if a red arrow animation appears and connects an equation with a problem, VoiceOver might say "red arrow animation" as it is describing the slide. Obviously, this does not tell Noah anything useful and actually disrupts his thoughts when trying to navigate the text on the slide. For more complicated animations, this can get even more confusing. Secondly, if a professor inserts a screenshot of text instead of a textbox, VoiceOver identifies that as an image and will not be able to read it. In these cases, assistants would have to use Alt-Text to transcribe all the words and equations themselves. Although this might save time for the professor, it creates more work for the BLV student and the assistants.

Being able to take notes is an important aspect to any student's studying. Although it was possible for an assistant to take notes for him, Noah found it more conducive to his learning if he took notes himself. These notes were not taken during lecture but were a form of self-studying. Noah took notes by using the Mac Notes on his computer and typing the text out in his own unique short-hand style. This way, he could organize the information by chapter in his notes and go back to reference them for the final at the end of the course. This was especially useful for analytical chemistry, which was math heavy. Noah would often type out practice problems and rework them himself later. A section of his chapter 9 analytical chemistry notes is shown in figure 7. Typing out the equations proved to be a great way for Noah to keep track of the problem. For simple problems, Noah could solve them in his head while working with his calculator, but typing out the problems proved to be a necessary learning aide for complex math problems. These notes were valuable since they could also be accessed months later.

Chapter 9
Using Standard Additions of a known concentration to calculate concentration of an unknown.
EX 1: The lithium concentration taken from a patient being treated with lithium for manic depressive illness was analyzed using flame emission spectroscopy. A sample of the serum gave a reading of 253 units for the intensity of the 671nm red-emission line. Then, 1.00mL of an 11.8 M lithium standard was added to 9.00mL of serum. This spiked serum gave a reading of 583 units. What is the original concentration of Li+ in the serum?
I_x/I_x+s = cx_I/cs_I(V_I/V_total) + cx_I(V_I/V_total)
253/583 = x/11.8(1/10) + x   (9/10)
253 * (1.18 + 0.900x)/583 = x
298.54 + 227.7(x)/583 = x
298.54 + 227.7(x) = 583x
298.54 = 583x (minus) 227.7(x)
298.54 = 355.3x
298.54/355.3 = 0.840
0.840

Figure 7: A section of Noah's typed chapter 9 analytical chemistry notes

Lastly, many STEM courses have started turning to online digital learning systems such as Achieve by Macmillan and OWLv2 by Cengage for their homework assignments. For sighted students, these are simple enough to navigate, but for BLV students they are very difficult. The homework for both analytical and organic chemistry was assigned on these platforms, so Noah could only do the assignments with an assistant there to navigate the website. Noah often became frustrated by this, saying, "I wish that [Achieve] was more accessible, because I would have been able to do the homework a lot more on my own, and we would not have been so rushed."[5] For BLV students, time is precious. Homework that might take a sighted person an hour to complete may take a BLV student two or three hours. It takes BLV students longer to navigate the homework, work the problem, and type out the answer. Noah would regularly receive extensions on his homework in order to complete it all in time since he would simultaneously meet with assistants to study as well. For test days, Noah reported spending five hours taking an organic chemistry test one Friday. The same test which was completed by sighted students in two hours. Even with an assistant present reading the problems, it takes a lot of time to understand the problem and be able to draw out the answers on the paper. Overall, any opportunity to save time or work ahead was valuable, so an online resource that is simple to navigate would be a huge benefit. The development of such a resource would eliminate a major barrier BLV individuals face.

This need for BLV accessible online resources extends not only to the digital learning systems but also to important STEM platforms like Microsoft Excel. Excel is the most valued tool across several fields, great for all kinds of STEM, and yet, Noah's computer technology is unable to navigate it well.[10] While in analytical chemistry, Excel is needed to perform statistical analysis and create graphs of data acquired in lab. Noah was unable to navigate Excel by himself and required an assistant to help him. There is great opportunity to create a more accessible platform in the future so that BLV students are able to navigate it themselves.

Laboratory Experience

Laboratory classes have traditionally been one of the main obstacles referenced to discourage BLV individuals from pursuing a STEM education.[11] Many well-meaning people argue that the lab environment is unsafe for BLV students. It is true that laboratories contain hazardous materials such as chemicals, heat sources, and the potential for broken glassware. However, with the right respect and safety guidelines in mind, BLV students can learn more from the hands-on experience in a lab than anywhere else. When asked if he ever felt afraid while in lab, Noah responded, “Not at all. You just use common sense and competence and then just respect for the equipment, right? And that's usually all you need.”[5] By being intentional with his movements and equipped with an appropriate level of cautiousness, Noah found that lab classes were one of the most valuable experiences he had taking his chemistry courses.

One of the best opportunities of laboratory work for Noah was to be able to actually feel the glassware he had previously only heard described. There is a major difference between hearing about it and getting to hold it in your hands in terms of understanding. After being able to actively participate in labs with an assistant by his side, Noah’s understanding of experimental concepts like titrations and standard additions increased significantly. Understandably, there were aspects to the lab experiments that Noah could not perform on his own. Many of the instruments used in lab are not accessible to BLV students. Even equipment as simple as an analytical balance could not be used alone since the digital mass is purely visual. In addition, Noah could not measure out large amounts of compounds with glassware like beakers and graduated cylinders, these had to be carried out by an assistant as well. Overall, although BLV students could not perform a lab alone, a wealth of information is learned from participating in them. Laboratory experiences and the STEM field should not be closed off to BLV students.

Concerning Braille

As this is a case study concerning STEM education of BLV individuals, some may be wondering how Braille has not been mentioned up to this point. Simply stated, Braille was found to be unnecessary in teaching Noah both analytical and organic chemistry. Further, it would likely be a hindrance if it were used. Adding Braille as a STEM accessibility is not as helpful as it may seem for two main reasons. First, not many BLV individuals actually know how to read Braille. A study organized by the National Federation of the Blind in 2009 found that less than 10% of the 1.3 million legally blind people in the United States were Braille readers and a mere 10% of blind children were learning Braille at the time.[12] With so few Braille readers, audio sources are much more important for educational purposes. Nevertheless, Braille technologies do exist for notetaking and STEM materials, like the BrailleNote. This instrument can convert an audible lecture to Braille for the student to reference later, however, this requires high Braille proficiency. This case study found that it is possible to teach both analytical and organic chemistry without the use of Braille. Noah could read Braille with low proficiency and only used it when labelling his tactile papers with the chapter number they belonged to.

Secondly, Braille cannot be read by sighted individuals, so any help explaining notes or concepts in Braille would not be possible. For example, there are organic chemistry textbooks made completely in Braille, but an assistant would be unable to help Noah understand something from the textbook if they cannot read it themselves. Noah also already took notes in standard English by typing them on his computer, so Braille was not needed there either. One caveat that must be acknowledged is that Noah's vision faded in high school. The circumstances of a BLV student who lost their vision earlier in life might change this approach. It is possible Braille would be more important to such an individual, so there must be some adaptability when working with students and their particular needs. Overall, this study found that Braille was unnecessary for learning since few blind people actually read it and it becomes an obstacle for the sighted assistants that help the BLV student.

CHAPTER FOUR

Conclusion

This case study has illuminated the common hardships that BLV students face in STEM courses as well as the effective methods to counteract those hardships. Above all, this case study is evidence to all those in doubt that a BLV student can succeed in the STEM field. Noah passed his analytical chemistry class with a B and currently has an A in his organic chemistry class. The mental acuity and determination to master chemistry that Noah displayed during the semester would make any educator proud. BLV students are absolutely capable of achieving great results in the STEM field; it merely comes down to providing accessible approaches to learning. To make this a reality, professors and assistants should be aware of how to approach teaching a BLV student and the strategies that have been proven to work well.

Professor Recommendations

The most important factor that determines the effectiveness of a professor teaching a BLV student is their willingness to adapt and work with that student through their unique needs. Ignoring everything else discussed so far, an open attitude on the part of the educator makes a world of difference to the BLV student and their success in the course. A professor with a willingness to work through difficulties becomes easier for the BLV student to approach, whether during office hours or for post-lecture questions. Noah confessed that it was difficult for him to seek out professors for help when they expressed closed-off and uncaring attitudes toward him.[5] These attitudes would usually lead to him trying to work out problems by himself, becoming less productive. BLV students are already going to need more time for assignments and tests than sighted individuals, so having a professor that understands and seeks to assist in meaningful ways contributes greatly to the student's morale and success in the course.

As far as concrete actions a professor can take to make their course more accessible, the lectures and the PowerPoints are the main two areas to consider. As stated previously, complex animations and screenshots of text instead of actual text make it difficult for a BLV student to navigate and find information on the slides. Although an assistant can use Alt-Text to manually convert everything, it just creates more work than necessary. The lectures are purely verbal, most commonly in conjunction with the PowerPoints. It is entirely unhelpful when professors refer to their slides saying phrases like "this equation" or "that image on the left." A BLV student would not be able to follow the lecture well without the professor using better descriptors for their slides. This would also aid the sighted students as well, since repetition of information and equations contributes to memorization.[13] As a whole, being open and mindful of time allowances as well as adjustments with the PowerPoints and lecture would greatly improve a BLV student's educational experience.

Assistant Recommendations

Having an assistant with competence in the course material is absolutely necessary for the success of the BLV student. Visual concepts need descriptions and tactile representations. It would be impossible for Noah to get by without someone helping him. Neglecting these one-on-one interactions is not an option. Organic chemistry assistant Yasmin Andrade confirms this about Noah, saying, “[I]f he can't see or feel it on the paper, he's never going to actually grasp the concepts of anything in organic chemistry. And teachers are so busy with all the students, they don't have time to be that intensive. It's a very personal learning experience.”[14] Whether it be working with the BLV student, preparing tactile representations of concepts, or transcribing PowerPoints, the role of the assistant is necessary and more intensive than that of the professor. The assistants are the ones that are going to be alongside the BLV student day-to-day and are of utmost importance.

Similar to the professors, assistants also need to have an open attitude and amicability for the studying environment to thrive. This is true for any sighted student as well, having a tutor that is patient and willing to troubleshoot makes a big difference. However, for the assistants, attitude will not suffice by itself. In order to properly work through a STEM class with a BLV student, prior knowledge of the material is needed. The assistants need to command a clear grasp of the course so as to not lead the BLV student astray with confusing or incorrect information. While interacting with several different assistants, Noah confirmed that having someone who had successfully taken the courses previously was a huge advantage over people who had not taken the class or who were also currently taking the class alongside him.

In addition, this case study found that having more assistants was a greater advantage for Noah than having only one. There are three main reasons for this: assistants could fill diverse positions, Noah could be subject to different teaching styles, and the assistants themselves could manage their time better. For organic chemistry, Noah had several people helping him in different ways. Some would sit with him during lecture and provide clarification on any questions Noah had mid-lecture, while others would work with him outside of class to study. Noah also felt he understood concepts better after hearing them from a couple different assistants since everyone would explain it in their own style. Being exposed to these different teaching styles gave Noah the opportunity to think about the information from a variety of angles. Finally, the most vital advantage was that the work load on any one assistant was lessened considerably by splitting the tasks. Students volunteering to work with a BLV student have their own classes and jobs at the same time. The assistants are the ones taking on the bulk of the work, so being able to divide this load makes the quality of each tutoring session increase since the assistants are not overburdened. The assistants in this case study were all offered some kind of compensation for their time as well, whether that be monetary or in the form of recommendation letters. While many assistants might do the work without such incentives, it is a great support for students in the middle of pursuing their own STEM careers.

Lastly, the time that assistants dedicate to working with BLV students does not go to waste. Besides lab experience, it is perhaps the most beneficial job that they can find for themselves. While tutoring Noah, the assistants found that reviewing the concepts and actively teaching solidified their own understanding of the material as well.[14] This case study found that such an arrangement benefitted both Noah and the assistants while he took analytical and organic chemistry. In 2021, a study published by the Science Journal found that disability innovation in the STEM field strengthens the field as a whole.[13] This connects back to how multiple information inputs and outputs can improve learning. For both BLV and sighted individuals, having opportunities to learn in different ways and be able to teach someone else results in greater mastery of the course.

Concluding Remarks

The main challenge that Noah identified in his experience pursuing a STEM field career was that educators simply do not know what actions to take to teach BLV students.[5] The accessible technologies and studying strategies analyzed in this case study seek to amend that by providing direction for future educators and fellow students looking to assist BLV students while they pursue their love of STEM. The more awareness and information is spread throughout the scientific community, the more useful tools and technologies for BLV students will be investigated. In his closing interview, Noah explained that his wish for the future "is to have more well-defined outlines, protocols, and guidelines in order to make things accessible for the blind in academia."[5] With this case study and future ventures into the accessibility of the STEM field, this wish can become a reality.

BIBLIOGRAPHY

(1) Baumer, K. M.; Lopez, J. J.; Naidu, S. V.; Rajendran, S.; Iglesias, M. A.; Carleton, K. M.; Eisenmann, C. J.; Carter, L. R.; Shaw, B. F. Visualizing 3D Imagery by Mouth Using Candy-like Models. *Sci. Adv.* **2021**, *7* (22). https://doi.org/10.1126/sciadv.abh0691.

(2) *Teaching Chemistry to Students with Disabilities: A Manual for High Schools, Colleges, and Graduate Programs*, 4th ed.; Milner, D. L., American Chemical Society, Eds.; American Chemical Society Committee on Chemists with Disabilities: Washington, DC, 2001.

(3) Cornell University. *Disability and Employment Status Report for the United States, 2017*. https://www.disabilitystatistics.org/reports/2017/English/HTML/report2017.cfm (accessed 2022-10-21).

(4) Harshman, J.; Bretz, S. L.; Yezierski, E. Seeing Chemistry through the Eyes of the Blind: A Case Study Examining Multiple Gas Law Representations. *J. Chem. Educ.* **2013**, *90* (6), 710–716. https://doi.org/10.1021/ed3005903.

(5) Noah Cook. Experiencing STEM Education as a BLV Individual., 2022.

(6) Brown, E. Disability Awareness: The Fight for Accessibility. *Nature* **2016**, *532* (7597), 137–139. https://doi.org/10.1038/nj7597-137a.

(7) Greenvall, B. R.; Tiano, A. L.; Chandani, A.; Minkara, M. S. The Influence of a Blind Professor in a Bioengineering Course. *Biomed. Eng. Educ.* **2021**, *1* (2), 245–258. https://doi.org/10.1007/s43683-021-00052-1.

(8) Sathian, K. Visual Cortical Activity during Tactile Perception in the Sighted and the Visually Deprived. *Dev. Psychobiol.* **2005**, *46* (3), 279–286. https://doi.org/10.1002/dev.20056.

(9) *Accessibility*. American Chemical Society. https://www.acs.org/content/acs/en/about/diversity/inclusivity-style-guide/accessibility.html (accessed 2022-10-11).

(10) Excel Dominates the Business World... and That's Not about to Change. *Market research consulting*, 2021.

(11) Nepomuceno, G. M.; Decker, D. M.; Shaw, J. D.; Boyes, L.; Tantillo, D. J.; Wedler, H. B. The Value of Safety and Practicality: Recommendations for Training Disabled Students in the Sciences with a Focus on Blind and Visually Impaired Students in Chemistry Laboratories. *J. Chem. Health Saf.* **2016**, *23* (1), 5–11. https://doi.org/10.1016/j.jchas.2015.02.003.

(12) National Federation of the Blind. Braille Literacy Report, 2009.

(13) Daehn, I. S.; Croxson, P. L. Disability Innovation Strengthens STEM. *Science* **2021**, *373* (6559), 1097–1099. https://doi.org/10.1126/science.abk2631.

(14) Yasmin Andrade. Tutoring a BLV Student Organic Chemistry, 2022.