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Commentary

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Implementation of Protocols To Enable Doctoral Training in Physical and Computational Chemistry of a Blind Graduate Student

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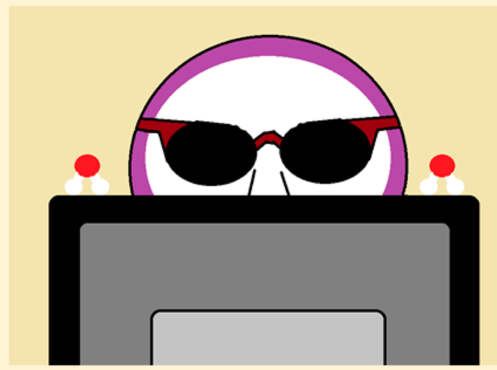
ABSTRACT: There exists a sparse representation of blind and low-vision students in science, technology, engineering and mathematics (STEM) fields. This is due in part to these individuals being discouraged from pursuing STEM degrees as well as a lack of appropriate adaptive resources in upper level STEM courses and research. Mona Minkara is a rising fifth year graduate student in computational chemistry at the University of Florida. She is also blind. This account presents efforts conducted by an expansive team of university and student personnel in conjunction with Mona to adapt different portions of the graduate student curriculum to meet Mona's needs. The most important consideration is prior preparation of materials to assist with coursework and cumulative exams. Herein we present an account of the first four years of Mona's graduate experience hoping this will assist in the development of protocols for future blind and low-vision graduate students in computational chemistry.



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INTRODUCTION

The World Health Organization estimates 285 million persons have visual impairments in the world, with 39 million completely blind.[1] Primary educators have been apprehensive in providing a science, technology, engineering and mathematics (STEM) education to blind students.[2] Adaptation of laboratory exercises for blind college chemistry students, such as titration experiments utilizing audio and tactile (Braille) cues, is in the literature from four decades past, but this early development appears to have been limited to an as-needed basis.[3] Recent efforts have been made to adapt chemistry lectures and laboratories for undergraduate students.[4] Tactile diagrams convey imagery such as chemical structures to blind users.[5] Tactile learning aids such as molecular models relate structural information to organic chemistry students.[6] Other efforts have focused on vibration to convey information from chemical instruments.[7] Recently, Pereira and co-workers introduced a web portal allowing the construction of simple organic structures for blind users[8] and Garrido-Escudero detailed a tactile approach[9] to inorganic chemistry nomenclature. Supalo et al. presented further ideas on making science accessible to blind and low-vision students.[10] Still, accessible resources are limited.

The National Center for Blind Youth in Science (NCBYS) has sought to alter this paradigm since 2004.[11] Basic science resources are becoming more readily available for elementary through high school students. While an influx of low-vision students into graduate programs is likely in a few years, there is a need for documentation of tools and techniques useful for these future students.

Herein we document the first four years of graduate work in computational chemistry at the University of Florida completed by Mona Minkara. At age seven, Mona was diagnosed with macular degeneration and cone-rod dystrophy. The progression of her condition has rendered her with only two percent vision in her left eye. The purposes of this article are (1) to document methods used to deliver large volumes of audio and visual information to Mona, (2) to point out considerations that have or should have been implemented to facilitate her work, and (3) to offer suggestions to future blind graduate students and their advisors. We hope this account will guide future graduate students, instructors, advisors, and disability offices.

DESIGN

Before Mona arrived on campus, it was known that readers would be required to verbally convey information to her and efforts were made to locate these assistants prior to her arrival. Additionally, she had expressed a need to have notes available in large print; however, the details of how this task would be reliably accomplished for her first semester graduate courses remained to be determined. These requests were made based upon Mona's undergraduate experience. Due to the more rigorous nature of a graduate program, as well as certain aspects that occur within a

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very constrained amount of time, the considerations that worked for her undergraduate education required expansion and augmentation. Since Mona's situation had no precedent at the University of Florida, much of the design of Mona's adapted program was developed on-the-fly, especially early in her Ph.D. pursuit. As more information was obtained regarding how to allow access to course materials, each subsequent semester was prepared further in advance as far as note preparation, text recordings and acquisition of slides and/or hand-outs.

■ IMPLEMENTATION

Readers

With the aid of UF's Disability Resource Center (DRC), a job description was posted in a jobs forum for a reader. The initial posting did not render capable applicants. Locating readers required advertisements placed in the right locations, such as near chemistry and biochemistry halls, and in a timely manner. Tailored job flyers assisted in obtaining a larger applicant pool of 30 people.

One of the selection criteria used for identifying good candidates involved asking them to describe images encountered in Mona's research. Figure 1 depicts a ligand docked in the active site of *Klebsiella aerogenes* (KA) urease. Applicants were asked to describe the image. Accurate descriptions were more important than nomenclature. With this image, it is important to read the title and state that there is a chemical compound centered on the page, surrounded by multicolored circles with three letter codes and a four-digit number. It is also important to state that there are different lines: arrowed, solid and dashed. Below is an example of a reader description that Mona would deem satisfactory:

> *Title: 1finalkawideopen-ZINC00388081. Holding the page horizontally, there is a compound in the middle surrounded by multicolored circles. Some components of the rings have arrows pointing to colored circles. The compound seems to be made of 2 rings in the middle, the ring on the bottom is open on 2 sides on the left. From the first ring there is a red point leading to ARG2082, a purple arrow pointing from* HN^+ *to ASP1967 and a purple arrow pointing from HN to* H_20*. From the bottom ring, there is a purple arrow pointing from* H_3N^+ *to ALA2109. The two rings are surrounded on the left side by a green/blue line, but it begins fading as it goes to the right. Surrounding the rings and the line are labels HIS, ALA, VAL, LEU, MET.*

Most of the applicants did not notice the title at the top of the page, or mention that there are multicolored circles.

Coursework

Resources such as audio recordings and PDF readers are lacking in physical chemistry. It is essential that materials be prepared ahead of time in order for a blind student to succeed in high level courses. During class, good note taking by the reader is essential. Ideally, lecture notes should be typeset in large font and recorded in advance of the lecture so that they can be reviewed without a reader present. During the first semester at UF, lecture notes typeset in 28 pt font, including equations, with each figure enlarged to fill an entire page, were provided by the instructor several days prior to the lecture. Additionally, it proved to be most useful to obtain and prepare the bulk of the notes prior to lecture. This allowed Mona to focus on the verbal cues of the instructor rather than struggling with visualizing the enlarged print copy in real-time. The note reformatting task can be

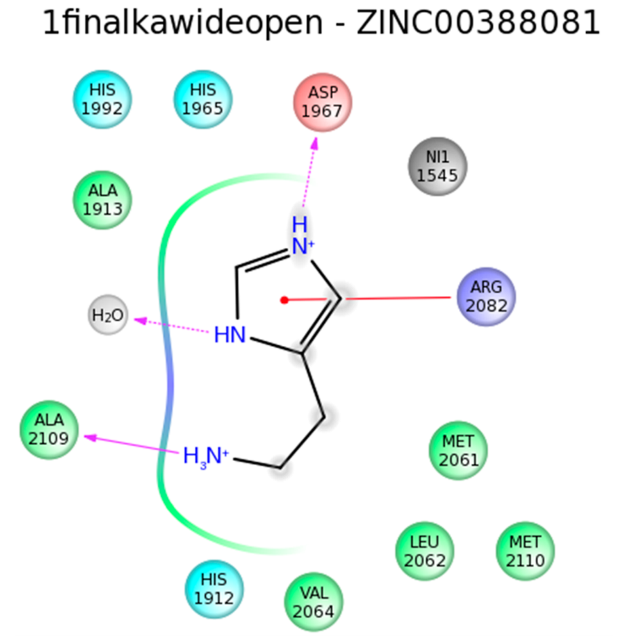

Figure 1. 2-Dimensional diagram of ligand interacting with *K. aerogenes* urease.

performed by a reader if sufficiently early access to the standard lecture notes is provided.

Cumulative Exams

Cumulative exams are an integral part of receiving a PhD in many graduate programs. A series of six cume exams are administered during the first two years in the graduate program in Physical Chemistry at the University of Florida. One point is earned for each full pass and a half point is earned for a "half-pass." A total of four points are required to quality for the PhD. Cume questions are based on reading material issued one week in advance of the exam date.

One difficulty with this cume policy is the finite time frame permitted for study, i.e., the topic was announced only one week prior to the exam. To address logistical problems, Mona's primary postdoctoral assistant, Dr. Michael Weaver, devised a system where he obtained the material ahead of time in order to record the necessary papers. Therefore, when students were given the relevant literature, Mona commenced study whether a reader was available or not. Indeed, Mona failed the first cume when materials were not prepared in advance. However, Mona she earned four passes in her first year and never failed any subsequent cumulative examination.

Research

Conducting computational chemistry research using molecular dynamics as a blind student is difficult. A barrier associated with Mona's research is that another individual must first visualize everything. Mona's first research project as a graduate student entailed molecular dynamics simulations on the *Helicobacter pylori* (HP) urease[12] enzyme and analysis of data.

HP urease is an enzyme with approximately 148 000 atoms (9744 residues) and the simulation was run in explicit water, adding another 150 000 atoms to the system (Figure 2). One technique used was detailing motion in terms of distance between set residue pairs (Figure 3). Trivial pieces of information such as titles, axis labels and units are of critical importance in the reader's description. Readers would describe any general trends: for example, the green line has an upward climb from 100 to 200 ns.

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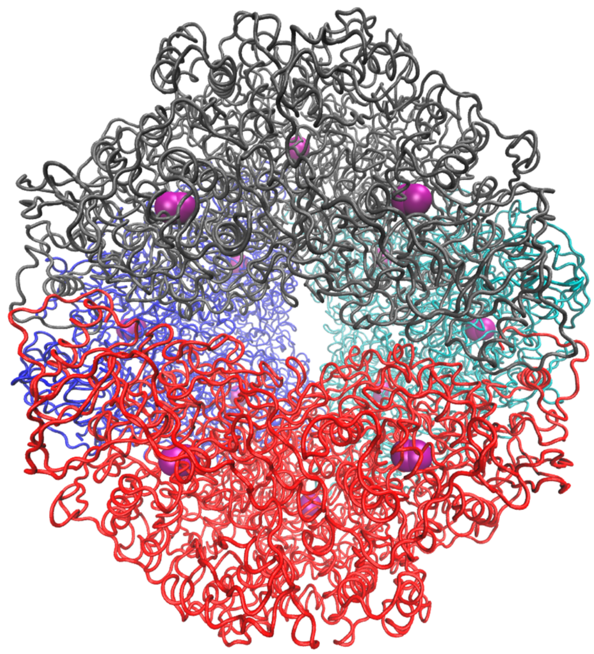

Figure 2. Representation of the *H. pylori* urease enzyme.

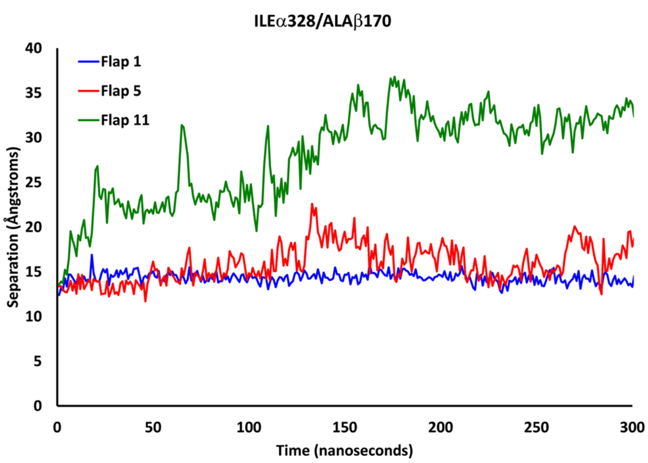

Figure 3. Residue separations in HP urease used to quantify extent of flap opening.

This mathematical approach to understanding molecular motion requires the reader to detail the occurrence of any minima, maxima, plateaus or other features on a Cartesian plot.

Another technique utilized by Mona involved the development of hypotheses that she could test by posing questions to a sighted person. Readers were required to describe in detail what they observe based on Mona's cues. This particular protein has 12 identical parts, so coloring the different parts using Visual Molecular Dynamics[13] permitted a better understanding of how the pieces fit together. Mona became adept at knowing which amino acids were present as well as their locations based on the sequence name. Mona's persistence exercised throughout her first two years of research on this enzyme culminated in the publication of a study on the motion of active site-covering flaps of HP urease in the *Journal of Chemical Theory and Computation*.[14]

Teaching

As a blind graduate student, Mona had an interesting time teaching for the general chemistry course at the University of Florida (CHM2045). Some individuals were apprehensive about a blind TA teaching a discussion section of the course. In the end, the students were impressed and the chemistry department asked her to teach again. PowerPoint slides were prepared for every discussion class. These slides were thoroughly studied to prepare for possible questions from students. A topic outline at the beginning of each PowerPoint presentation was provided to allow the class to identify topics requiring special attention. Class was interactive; Mona's lectures were followed by discussions with her students. Being aware of her blindness, students spoke out and were very vocal. The students enjoyed this interaction. Mona's teaching experience caused her to consider teaching as a possible career path.

Disability Resource Center

Choosing a school with a great DRC is paramount for the success of a blind graduate student in chemistry. The DRC here at the University of Florida is truly amazing in terms of the equipment provided and hiring of readers in her support.

■ POSTDOCTORAL PERSPECTIVE

A postdoctoral associate working with a low-vision student has a bifurcated role. The traditional role as a mentor to graduate students is applicable, and there is the added role of serving as eyes for the student in order to convey information. Too little mentoring results in the low-vision student being deprived of the same learning opportunities as other graduate students. Too much mentoring could result in reduced intellectual ownership of the research product. Both cases are detrimental to the educational process, and it is crucial for the postdoc to strike the appropriate balance between the two extremes.

■ ADVISOR AND DRC PERSPECTIVE

The process by which a graduate student selects a Ph.D. advisor is an important task. In Mona's case she wanted to be in a Computational/Chemistry/Biology group and wanted an advisor with a hands-on approach to research and research group management, which fit Kenneth Merz's profile quite well. One difference between Mona and other graduate students is that she runs a small staff and trains them, which adds additional burden to the graduate experience. The second important difference for the advisor is the need to spend time visually reviewing the student's research.

Along with the support of a proactive advisor, the support of the university's Disability Resource Center is critical for a student with a visual impairment in an academic program where technology does not provide the necessary level of access to the course (e.g., textbooks, hard copy resources, homework sets, exams). When she met with the DRC at the University of Florida, she shared her insight on what accommodations were provided in the past and what accommodations she felt would be needed as a student in a graduate program.

■ CONCLUDING REMARKS

A successful graduate education for Mona has required an intense, coordinated effort on the part of many different individuals as well as a strong commitment by Mona herself. While certain speed bumps were encountered along the way, it was simply the nature of said impediments that differed slightly from the norm. Through carefully planned adaptation of the curriculum and advanced preparation of recorded and large print materials we were able to overcome the majority of these hurdles. The most critical aspect of preparing these materials is

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coordinating with faculty instructors well in advance in order to acquire notes, slides, handouts, and reading material for enlarging and recording. The advanced preparation was crucial in allowing Mona to have equal study time compared to her peers, not in gaining extra time. This advanced preparation would also be critical for blind students who read Braille. We hope that this account will aid in the future education of blind and low-vision students who aspire to higher education in chemistry and other STEM related fields.

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Notes

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