# Engineering Education for Visually Impaired Students

**Dr. Deborah M. Grzybowski, The Ohio State University**

Dr. Deborah Grzybowski is a Professor of Practice in the Department of Engineering Education and the Department of Chemical and Biomolecular Engineering at The Ohio State University. She received her Ph.D. in Biomedical Engineering and her B.S. and M.S. in Chemical Engineering from The Ohio State University. Her research focuses on making engineering accessible to all students, including students with visual impairments, through the use of art-infused curriculum and models. Prior to becoming focused on student success and retention, her research interests included regulation of intracranial pressure and transport across the blood-brain barrier in addition to various ocular-cellular responses to fluid forces and the resulting implications in ocular pathologies.

**Dr. Tiffany Wild, The Ohio State University**

Dr. Tiffany Wild began her education career as a middle school science and math teacher. Her interest in visual impairment began when students with visual impairments were placed in her classroom without any support. Those students inspired Dr. Wild to become a Teacher of Students with Visual Impairments (TVI). As a TVI, she has worked as a teacher's aide for students with visual impairments in an early learning center and as an itinerant teacher for Project PAVE. Dr. Wild was awarded a prestigious doctoral fellowship with the National Center for Leadership in Visual Impairments to pursue her doctoral degree and her dissertation was awarded the "Dissertation of the Year" by the Council for Exceptional Children's Division on Visual impairment.

Currently Dr. Wild is an assistant professor in the Department of Teaching and Learning in the College of Education and Human Ecology and coordinates the program in visual impairment. She also is the president-elect for the Division on Visual Impairment and Deafblind and President of the Ohio Chapter for the Association for Education and Rehabilitation of the Blind and Visually Impaired. Her research focuses on science education for students with visual impairments. Dr. Wild has published and presented both nationally and internationally. It is through her research endeavors that she has been asked to be a co-founding member of the National Center for STEM Education for students with visual impairments, complete research on national STEM programming for the National Federation of the Blind, invitations to present at national, state, and local conventions.

**Miss Se Jeong Yang, The Ohio State University**

**Work in progress: Bioengineering Education for Students with Visual Impairments**

Engineering Education for Students with Visual Impairments (EEVI) is a two-year professional development program for teachers of students with visual impairments (TVIs), targeting grades 5-12 focused around bio-engineering. The overarching program goals are 1) Increase the science, math, and engineering content knowledge for TVIs; 2) Increase TVI's capacity to teach science, math, and engineering concepts to students with visual impairments (VI); 3) Increase TVIs efficacy in science, math, and engineering; 4) increase TVIs capacity to make modifications and accommodations for students with VI to pre-existing science, math, and engineering lesson plans; and 5) Improve students' with VI achievement in science, math, and engineering. To date the TVI professional development, which was intended to accomplish the first four goals, has been completed and post-professional development data are being analyzed. Determination of any affect these interventions have had on the students, goal five, will take more time to assess. This paper will focus on the development of 3D printed models as teaching tools to help remove barriers and misconceptions that VI students have with understanding math, science, and engineering concepts. The TVIs were given professional development to support them in creating 3D models using computer aided design tools, and how to print these models in their class.

## Background

Currently 61,739 students in the US are VI (American Printing House for the Blind, 2015). A major gap exists between general education teachers who do not have the pedagogical expertise to teach students with VI and qualified TVIs who do not understand the content well enough to support the student and the general education teacher. TVIs are not required to take courses in subject specific matter and general education teachers are often given little training in teaching students with visual impairments. The poor preparation of general education teachers to teach students with VI is the root of many of these problems (Norman Caseau, & Stefanich, 1998; Rule et al., 2011). At the same time, teachers of students with VI (TVI) are ill-prepared in STEM content and are unable to help with most of these barriers (Kapperman, Heinze, & Sticken, 2000). The lack of preparation for the TVIs creates an issue not only with competency, but also with a lack of self-efficacy in math, science, and engineering which creates anxiety.

According to Beck-Winchatz and Riccobono (2007), the majority of students with VI are following general education curricula. However, less than 30 individuals with VI earned a science and engineering research doctorate on average each year from 2001 to 2009 compared to 25,600 people without a disability on average per year during the same time period (NSF, 2012). Lack of higher level degrees in the science and engineering fields do not reflect the fact that students with VI have the same spectrum of cognitive abilities as sighted peers (Kumar, Ramasamy, & Stefanich, 2001) and with appropriate accommodations can master high-order concepts (Jones, Minogue, Oppewal, Cook, & Broadwell, 2006).

**Professional Development Curriculum**

Math and science teachers from the public state school for the blind who participated in the 120 hours of professional development activities received 15 weeks of an asynchronous online course in science, math, and engineering content and education for students with VI. The initial half of the course was based on the textbook "What is Life?" Phelen, 2015) and the teachers completed modules for each chapter on the textbook LaunchPad program. The second half of the course consisted of readings and reflections on teaching STEM content to students with visual impairments, a review of inquiry-based teaching methods, infusing dramatic inquiry into STEM pedagogy, and teaching for conceptual change. Additional support was provided in the form of two afternoon face-to-face sessions to learn about online resources for teaching STEM content. During the following summer, the teachers were provided a 40-hour summer institute where they were taught about infusing assistive technology into lesson plans, teaching mathematics content to students with visual impairments, and the basics of how to create 3D printed models for use in the classroom using OnShape, a readily available free online CAD software program.

**Instruments**

The instrument used in this study was created with the assistance of already developed instruments. The first 59 questions on this instrument were based on the Ohio Learning Standards (ODE, 2011) identified misconceptions in biology content directly related to biology, heredity, DNA, and evolution. Each identified misconception from the Ohio Learning Standards was turned into a true or false question. In addition to the biology content knowledge instrument, the other instruments included the Mathematics Anxiety Rating Scale (MARS-R), the Teaching Efficacy Beliefs Instrument (STEBI and MTEBI), and pre- and post- professional development interviews.

All teachers in this program completed the training during year one.

**3D Printing**

Another major aspect of the training and additional support being received by the teachers in the EEVI program is on learning how to design computer aided design (CAD) models and print them using 3D printers. The important educational objective here is to teach them how to create and incorporate the models into their classrooms. In addition to the TVI created models to support classroom learning, researchers are working to develop models for the teachers to use in their classrooms in the future. Currently a eukaryotic cell model has been developed with a scale factor of 10,000x.

Understanding the basics of cellular structure and function is a critical cornerstone of the biological sciences, but can be difficult to conceptualize due to the drastic size and scale difference from our natural experience. In conventional cell biology education, sectioned renderings and microscopy are the primary media used to illustrate these concepts. Unfortunately, this limited media often translates poorly when designing curricula for educating visually impaired students. To this end, the manipulatives produced during this project were meant to translate the conventional media into tactile models – providing visually impaired students with the same information as their sighted peers would receive through visual renderings.

Based on early feedback given by the TVIs participating in our focus group, one of the major challenges to creating these models is that many of the severely visually impaired students are unaccustomed to cross-sectioned or 'cut-away' drawings the way most sighted students would be. Many struggle with conceptualizing where the distinction lies between layered cross-sections, and how the model before them fits into the full 3-dimensional representation of the object as it actually exists. Rather than attempting to replicate sectioned textbook drawings then, our approach focused on creating an enlarged true-to-scale representation of a cell and cellular components, which could be disassembled to provide detail on the structure and function of various organelles.

Based on multiple literature sources, we complied a range of true size measurements for the various critical eukaryotic organelles (as shown below), and scaled up by a factor of 10,000x to achieve a final cell model size that was roughly 60cm (~1 ft) in diameter, which we believe will allow each organelle to be felt in sufficient detail to distinguish structure and provide insight into its function. Details of the modeled organelles are shown in Table 1.

*Table 1. Typical eukaryotic cell dimensions.*

| Organelle | Size in μm |
|---|---|
| Average Cell | 30 um |
| Nucleus | 7.5-10 um |
| Nucleolus | 2.5 um |
| Plasma Membrane | 0.009 um thick |
| Mitochondrion | 0.2-1 um wide x 3-10 um long |
| Ribosome | 0.025 um |
| Endoplasmic Reticulum | 0.5 um thick (Membranes 0.009 mm; 0.03 mm lumen between) |
| Golgi Complex | 1 x 1 um (membranes thickness same as ER) |
| Microtubules | 0.02 um diameter |
| Microfilaments | 0.007 0.5-1 um diameter |
| Lysosomes | 0.2-2 um |
| Peroxisomes | 3 um |
| Cell Wall | 1-2 um thick |

3D models were then developed using Solidworks and Autodesk CAD software suites to create the EEVI cell models to be 3-D printed. Figure 1 shows a rendering of the endoplasmic reticulum, golgi complex, mitochondria, and lysosomes. Another CAD model view is shown in figure 2, where the nuclear membrane, golgi complex, centrioles, mitochondria, lysosomes and peroxisomes are visible. Figure 3 shows the prototype 3D printed eukaryotic cell model. The models will be finished and painted in primary contrasting colors for the low vision students.

*Figure 1. Solidworks CAD model of partial eukaryotic cell.*

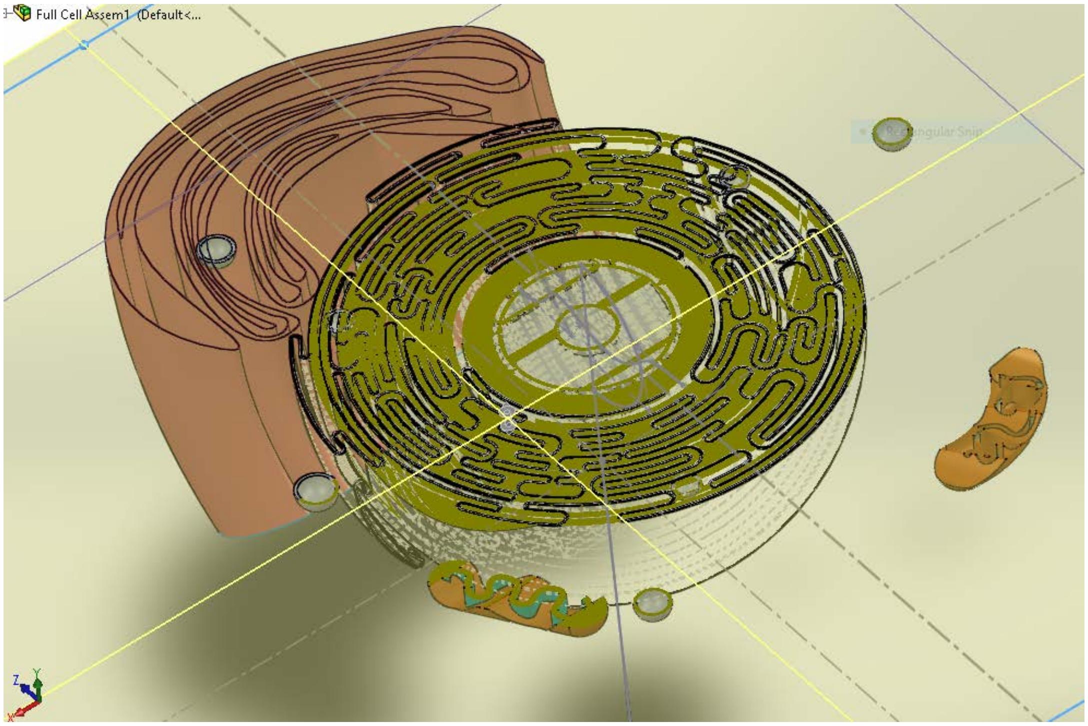


*Figure 2. Solidworks CAD model showing golgi, nuclear membrane, mitochondria, centrioles, and lysosomes.*

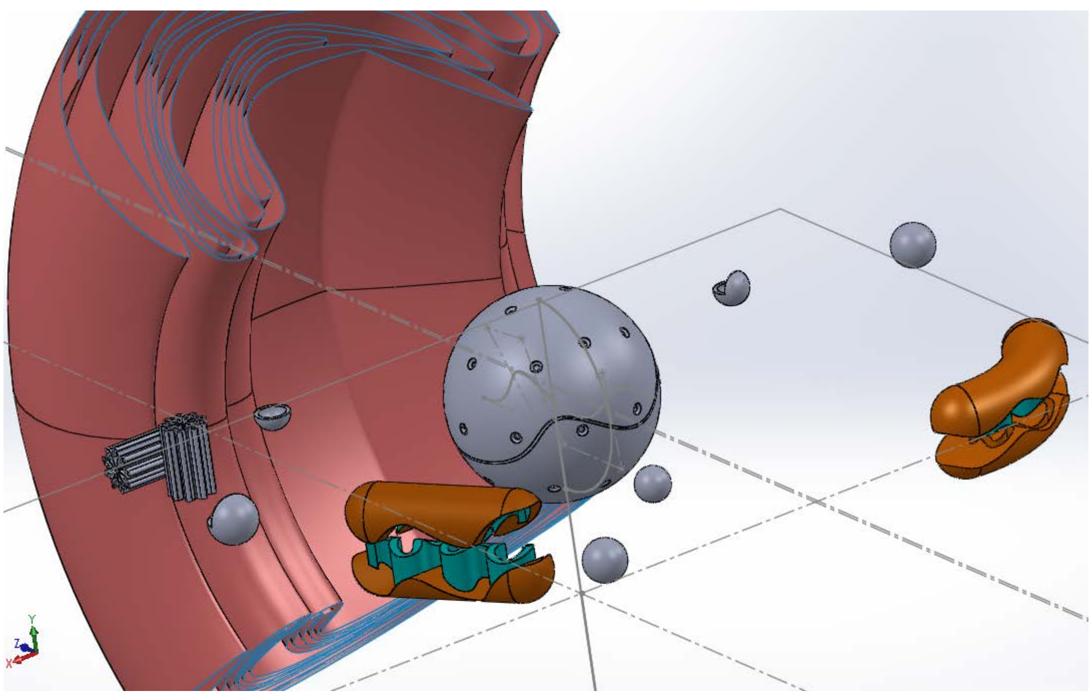

*Figure 3. Prototype 3D printed eukaryotic cell model.*

In addition to biology content knowledge, the teachers have been taught the engineering design process, and have developed a four-week comprehensive problem-based learning curriculum to bring together the new content knowledge with the engineering design process. This curriculum called Project B.O.V.I.N.E. (BioEngineering Opportunities for VI NextGen Engineers), which focuses on reducing methane production at a dairy farm, will be taught in the school this spring.

**Participants of the program**

A partner school was selected based upon their expertise, experience, and willingness to participate in this project in order to successfully affect the academic achievement of students with VI. The partnership consisted of a public residential school for the blind where children from all over the state with severe visual impairments can obtain the academic modifications to curriculum and the support services they need. Students at this school had a very low passing rate on state assessments in both math and science.

The teachers asked to participate in the project were selected based upon the content and age of children they taught. Five teachers from the partner school participated in the program. Four female and one male instructor participated in the program. All teachers taught at the school in the subject areas of math and/or science. These teachers also taught students in middle and high school.

## Discussion and Future Work

Teachers were given a content assessment of their knowledge and understanding of bioengineering before and after participation in the professional development session. Data collected from this effort is being reviewed and will be presented at the conference. The trend shows a positive increase in content knowledge levels of the teachers. In addition, the high school math and science teachers have gained confidence in using the 3D printer in their classroom with the students and have successfully integrated its use into their curriculum. It is expected that the high school math and science teachers will have larger gains in content knowledge, but that the middle school teachers will have larger gains in self-efficacy and decreases in anxiety. Further results from both the quantitative data and the ethnographic data will be available in the future.

## References

American Printing House for the Blind (2015). Distribution of eligible students based on the federal quota census of January 6, 2014. Available: http://www.aph.org/federal-quota/distribution-2015/

Beck-Winchatz, B. & Riccobono, M. (2008). Advancing participation of blind students in science, technology, engineering, and math. Advances in Space Research, 42, 1855-1858.

Jones, M.G., Monogue, J., Oppewal, T., Cook, M.P., & Broadwell, B. (2006). Visualizing without vision at the microscale: Students with visual impairments explore cells without touch. Journal of Science Education and Technology, 15(5-6), 345-351.

Kapperman, G., Heinze, T., & Sticken, J. (2000). Mathematics. In A.J. Koenig & M.C. Holbrook, (Eds.). Foundations of education: Volume II. Instructional strategies for teaching children and youths with visual impairements. New York: American Foundation for the Blind. 370-399.

National Science Foundation, Division on Science Resources Statistics, (2009, January). Women, Minorities, and Persons with Disabiitites in Science and Engineering: 2009, NSF 09-305, Arlington, VA

Norman, K., Caseau, D. & Stefanich, G. (1998). Teaching students with disabilities in inclusive science classrooms: survey results. Science Education, 82, 127-146.