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Education Corner

Jodi Davenport is Director of Research in the STEM Program at WestEd. Her research and development is focused on transforming science and math instruction and assessment to enhance student learning and engagement. Davenport's work includes significant collaborations with leading scientists and educators to develop educational interventions based on the latest cognitive science research.

Matt Silberglitt, Senior Research Associate at WestEd, contributes to and manages activities for science curriculum, instruction, and assessment research projects. Prior to his current position, Silberglitt managed development of large-scale science assessments. He has taught high school science, served as an instructor for college courses, and as a volunteer science teacher in an elementary school.

Arthur Olson is the Anderson Research Chair Professor in the Department of Integrative Structural and Computational Biology at The Scripps Research Institute and founder and director of its Molecular Graphics Laboratory. His laboratory has developed, applied and distributed a broad range of molecular modeling and visualization software tools over the past 30 years.

In Touch with Molecules: Improving student learning with innovative molecular models

by Jodi Davenport, Matt Silberglitt, Arthur Olson

Model of self-assembling virus developed by Artur Olson. ***See video.***

Introduction

How do viruses self-assemble? Why do DNA bases pair the way they do? What factors determine whether strands of proteins fold into sheets or helices? Why does handedness matter?

A deep understanding of core issues in biology requires students to understand both complex spatial structures of molecules and the interactions involved in dynamic processes. A collaboration between the Scripps Research Institute, and WestEd, (**www.wested.org**) seeks to make the molecular world accessible to students using innovative 3D-printed models and augmented reality.

Background

Dr. Arthur Olson, director of the **Molecular Graphics Lab at The Scripps Research Institute**, is a pioneer of innovative ways to visualize molecular processes. Typically, visualizations of complex biomolecules had been limited to representations on a two-dimensional computer screen. At the dawn of 3D printing, Dr. Olson saw an opportunity to create physical models of molecules based on research-based findings about structure, such as those available in the PDB archive. By embedding magnets into 3D-printed structures, Olson's group found they could represent polar interactions such as electrostatic complementarity and hydrogen bonding. Combining 3D printing with magnets produces models capable of demonstrating concepts such as viral self-assembly and protein folding.

For instance, Olson developed a model of poliovirus that self-assembles when the component pieces are shaken in a closed container (**see video**). The ability to self-assemble emerges because the shapes and complementary electrostatics of the poliovirus sub-units were used in the design of the model. The model's ability to self assemble was not specifically designed.

Further, the protein folding kit demonstrates polypeptide assembly and folding. Magnets representing hydrogen bonds assist the folding of secondary structures such as beta sheets and helices. Because the geometry of each component is based on the detailed nature of the polypeptide backbone, characteristics such as the twist of beta sheets, and the flexibility of alpha helices emerge upon assembly.

Protein folding kit

In Touch with Molecules Projects

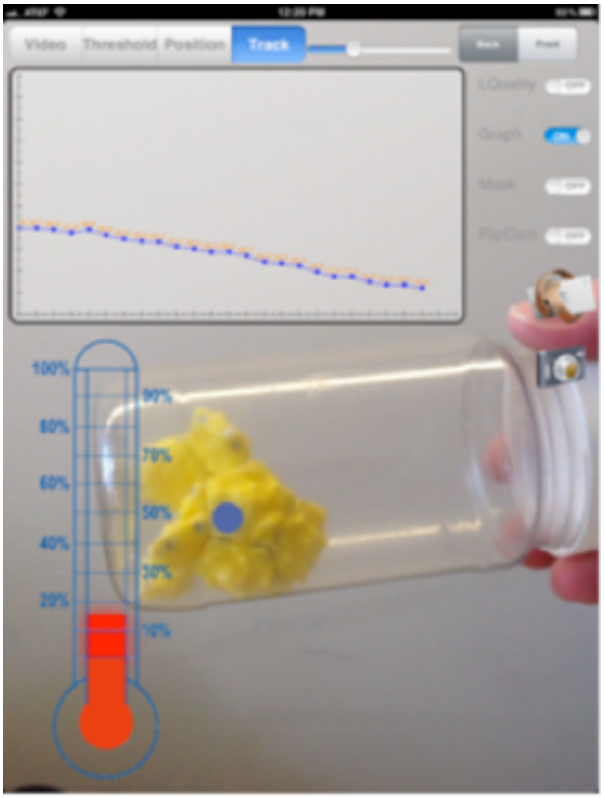
Recently Dr. Olson has partnered with Dr. Jodi Davenport and Mr. Matt Silberglitt at WestEd to explore how these cutting-edge models make complex concepts accessible to students. With funding from the National Science Foundation, and the US Department of Education's Institute of Education Sciences, the In Touch with Molecules projects aim to explore how these models can help students learn and identify ways to integrate the models into real classroom settings. These projects aim to research how students learn using the models and to iteratively refine the models and curricular activities.

A model of DNA

To date, the projects have refined existing, and developed new, lesson plans to accompany models demonstrating concepts of self-assembly, protein folding, DNA and enzyme structure and function. We have tested the new models and materials in classrooms at 3 different high schools with a wide range of students. To date, seven high school classrooms have tested a series of inquiry-based activities that guide students as they explore the virus and DNA model and test hypotheses about factors influencing rates of assembly. Preliminary pre-post measures demonstrate statistically significant learning gains on conceptual understanding. Further, graduate students at the Scripps Research Institute have used the protein folding model and instructional materials to explore how primary structures and interactions determine handedness and constrain the formation of secondary, tertiary and quaternary structures. As one graduate student stated, "We talked about alpha helices and beta sheets a lot, but this is a lot more useful!"

Ongoing work

In addition to the physical models, the project is exploring ways of incorporating augmented reality by embedding barcode-like markers to add another dimension of molecular visualization. When the models are held in front of a tablet's camera, software recognizes these markers and displays an augmented reality image. On the screen, the user sees the physical model overlaid with additional data and visual information. The software tracks the motion of the physical model in real time, so the display updates dynamically as the user manipulates the model. For example, in the Shake My Virus app (available on the App store) we track the speed of shaking of the viral assembly model and represent the rate of shaking in a thermometer to help students connect kinetic energy with temperature.



The Shake My Virus app can track the speed of shaking of the viral assembly model

Additional models and lessons are under development and we will be updating our website at molecules.wested.org as the project evolves. We believe that integrating these technologies with classroom activities will transform how conceptually difficult topics in biology are taught to a wide range of students.

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