The Helpful Hydrogel: Hands-On Biomaterials Property Manipulations for Tissue Engineering and Drug Delivery

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Statement of Purpose: Middle school (5th-8th grade) represents a critical time where many students lose interest in the fields of science, technology, engineering and mathematics (STEM). Employing hands-on inquiry-based learning is critical to maintain student's interest in STEM [1]. Thus, new and exciting modules need to be developed and deployed to increase student excitement in biomaterials science and engineering. We designed a learning module specifically for 5-8th grade based on hands-on, interactive methods. Students were introduced to hydrogels, their formation, network structure, properties, and applications. Students learned how hydrogel composition can be tuned to achieve target material properties such as mesh size and stiffness. Discussion included how tissue properties relate to their function within the body, and the importance of matching biomaterial properties to that of the host tissue. In addition, stem cells and the ability of material properties to influence the behavior of these therapeutic cells were discussed. The use of hydrogels for the controlled delivery of drugs was also investigated through diffusion experiments. To facilitate dissemination, the module provides background material, step-by-step instructions, post-lesson assessments, and suggestions for adaptation. This module can be conducted by a college-educated adult with minimal scientific training, for an initial setup cost of $20 and a recurring cost of $20.

Methods: After an initial introduction to biomaterials, directed brainstorming was employed to help students identify biomaterials in the world around them, focusing on hydrogels. By varying the weight percentages of gelatin (Jell-O®) in hydrogels, students learn how hydrogel composition can be tuned to produce gels with target properties like mesh size and stiffness (Figure 1). Students utilize tactile investigation to investigate the stiffness of tissues in the body (chicken fat, muscle, and bone) and discuss how the stiffness of the tissue allows for specific functions within the body (cushioning of fat, structural stability of bone, etc.). Students then identify which hydrogel is best suited for use in each of the previously-discussed tissue environments. The exciting concept of stem cells, their in tissue healing, and the role biomaterials properties such as stiffness play in controlling stem cell behavior is also discussed.

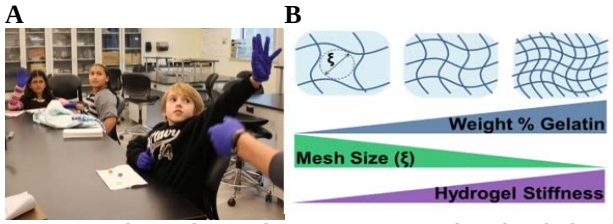

Figure 1: Students utilize tactile investigation (A) to learn how hydrogel composition (weight %) can be altered to control resulting material properties such as mesh size and stiffness (B).

In addition to theoretically investigating stem cell behaviors, students learned how alterations in hydrogel composition can be used to control the rate of drug release. Students examined the diffusion of food coloring through hydrogels of varying weight percent gelatin, and understand the relationship between the rate of drug diffusion and hydrogel properties such as mesh size (Figure 2). Students then brainstorm potential applications for the varying drug release profiles observed. Options for advanced modifications are also presented, involving students collecting images of the diffusion experiment and quantifying the rate of diffusion in each hydrogel.

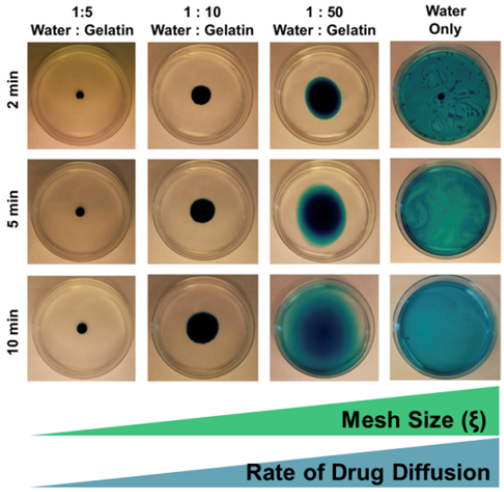

Figure 2: Students investigate how hydrogel composition can be altered to control the mesh size of the hydrogel networks, controlling the rate of drug diffusion (food coloring) within the biomaterials.

Results: This module provides a summary of relevant scientific background, detailed list of required materials and suggested sources, instructions for module preparation and setup, a script to conduct classroom activities, and cost-saving modifications. The clearly-defined learning objectives address four National Science Education Standards for 5-8th grade [2], with student learning assessed in terms of scientific vocabulary learned and a post-module assessment worksheets. Student excitement in response to the module has been extremely positive, with students reporting "I learned lots of scientific, cool things" [3].

Conclusions and Future Directions: The developed module represents an engaging, hands-on method to teach middle school students about biomaterials and fundamental principles of biomaterials science. It has been extremely well-received when used in schools in the Rochester, NY area, and we are working to disseminate the module to other biomaterials research groups and middle school science teachers.

References:1. Gibson, H.L. *et al. Sci Educ*. **86**(5) 2002.
2. Council, N.R. 1996, The National Academies Press.
3. Palmiero, L. 2012.