Exploring Biomaterials: Diffusion and Encapsulation in Drug Delivery and Cell Therapy

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Statement of Purpose: Science and engineering outreach programs aimed at middle school age students can significantly increase the interest in pursuing STEM fields and careers [1]. Further evidence indicates that hands-on experiences, exposure to real-world applications, and role models within the scientific community help improve understanding of scientific concepts and inspire students to pursue STEM careers [2]. The Vaicik laboratory team located in Chicago at Illinois Institute of Technology (Illinois Tech) has developed fun hands-on activity modules focused on introducing students to biomaterials for drug delivery and for cell therapies, the learning concepts focus on illustrating diffusion (Module 1) and encapsulation (Module 2). This project is designed to be deployed in a regular classroom without any additional special science equipment as many of the local Chicago area schools lack science resources. Illinois Tech mission is focused on providing a working and learning environment in which all members of our community are able to realize their full potential. The Vaicik lab supports that mission by providing these outreach activities to inner city schools in Chicago to introduce the next generation of students to biomedical engineering. To help address the challenges in our current schools and inspire future engineers, we have designed these activities to engage students to explore and excite their creativity. Additional we developed the activity to guide students to make hypotheses, observations, and conclusions about the chemistry behind biomaterials involved in hydrogels –crosslinked structured made from building blocks called polymers- and their applications in drug delivery. In this activity, students will learn about what a polymer is, about the vast uses for polymers, and about how polymers chemically react to form hydrogels. From skincare to contact lenses to disease models and even their boba bubble tea, students will start spotting polymers everywhere and see how science is the foundation of the everyday and the extraordinary.

Target Audience and Logistics: This activity is targeted for middle schoolers ages 11-14 (6th-8th grade), and the full educational module is designed to be completed in 45 minutes. The project can also be divided into two smaller modules for 20 minutes each for the activities. This activity is well-suited for the average class size of 20-30 students, where they can work in groups of 2-4. When used for larger student group sizes, then individual module (1) has been successfully used to allow for groups up to 50.

Materials: All materials are non-toxic, commercially available, and easily sourced online or in large retail stores (Table 1). Equipment used to prepare and mix the materials includes small droppers, a blender or electrical mixer, and a scale. The solutions are pre-made and brought to the activity. For **Module 1**, a 2% (w/v) sodium alginate solution and a 1% (w/v) calcium chloride solution are prepared separately. For **Module 2**, 2%, 3%, and 4% (w/v) sodium alginate solutions and a 1% (w/v) calcium chloride solution are prepared separately.

Activity: At the start of the activity, students receive a handout, which illustrates the alginate crosslinking process and has sections for each module. It explains how sodium alginate, a natural polysaccharide, interacts with calcium ions (Ca^{2+}) to form a gel through ionic bonding, replacing sodium ions and creating crosslinks that turn the liquid into a stable, flexible hydrogel.

Module 1 Diffusion: The graduate student facilitates a discussion with the small group before students fill out the Module 1 Diffusion section of the handout. The discussion encourages students to predict what will happen when the red food-colored alginate solution is dropped into the clear calcium chloride solution. Afterward, students take turns adding the alginate solution to the calcium chloride, forming red alginate beads. They then probe the beads, observing how the red color gradually fades as the dye diffuses into the surrounding liquid. Finally, students complete their handouts by recording their observations and reflecting on the diffusion process.

Module 2 Encapsulation: Students will first engage in a discussion and complete the corresponding section of the **Module 2 Encapsulation** handout. In this module students will be challenged to embed a single piece of glitter inside an alginate bead by adding it to the precursor solution. Through this process, they will experience the difficulty of evenly mixing glitter—similar to the challenge of incorporating living cells into viscous solutions. After forming the beads, students will discuss methods to verify that the glitter is fully encapsulated. Finally, students will work to evenly distribute the glitter within each bead, refining their technique through trial and observation. They will aim to consistently create glitter-encapsulated beads, making 10 in a row to demonstrate the process of manufacturing.

Table 1

Materials	Amount	Cost ($)
Sodium alginate powder	100 g	4
Calcium chloride powder	20 g	4
Water	5 L	~0
Food coloring and glitter	1 pack	2
Zip bags	30	2
Plastic cups	60	10

Conclusion: This activity teaches students about alginate biomaterials, diffusion, and encapsulation for drug delivery. By the end, students will: 1) Understand diffusion and its role in material interactions, 2) Learn how biomaterials like alginate are used for encapsulation, and 3) Explore polymer properties and their applications in hydrogels for drug delivery and biomedical engineering.

Assessments: Students will take a pre-test on diffusion, encapsulation, and their perceptions of STEM-related careers. After the activity, they will complete a similar test to assess the knowledge gained.

References:

[1] N.P. Moreno, B.Z. Tharp, G. Vogt, A.D. Newell, C.A. Burnett, Preparing Students for Middle School Through After-School STEM Activities, J. Sci. Educ. Technol. 25 (2016) 889–897.

[2] Y. Chen, W.W.M. So, J. Zhu, S.W.K. Chiu, STEM learning opportunities and career aspirations: the interactive effect of students' self-concept and perceptions of STEM professionals, Int. J. STEM Educ. 11 (2024) 1–21.