Cost-Effective, Inquiry-guided Introductory Biomaterials Laboratory for Undergraduates

Sarah E. Stabenfeldt, PhD and Casey J. Ankeny, PhD
School of Biological and Health Systems Engineering, Arizona State University, Tempe, AZ

Statement of Purpose: Inquiry-guided instruction has been shown to be a more effective teaching strategy than traditional instruction strategies. More specifically, research shows that inquiry-guided courses lead to improved critical thinking, increased ability for independent inquiry, increased responsibility for one's own learning, and intellectual growth (Lee, et al. 2004) as compared to traditional, lecture-based instruction. In inquiry-based instruction, students work in a self-directed manner to explore and interpret outcomes based on investigation of their own questions (Prince and Felder, 2006). Here, we describe a cost-effective, sustainable introductory biomaterials laboratory for undergraduates using inquiry-guided instruction at a large public university.

Methods: The four laboratory components focus on 1) the structure and function of poly (methyl methacrylate) commonly used as bone cement, 2) the structure and function of alginate hydrogels commonly used for drug delivery, 3) metal toxicity using brine shrimp as model system with applications to medical device toxicity, and 4) cell adhesion with respect to different surfaces to explore *in vivo* reactions to biomaterials. Each of the four individual lab components lasted for two to three weeks. During the first week, students are provided with a list of available materials pertaining to the lab component and worked with group members and the instructor to devise and test a custom hypothesis instead of using "cookie cutter" laboratory manuals. In the second week, students performed experiments to test their hypotheses. During the last week of the module, student performed statistical analysis appropriate for their custom experimental design. Each lab has been scaled so that it may be completed in 90 minutes. This allows for multiple mini-sessions in the allotted lab period, resulting in smaller groups and a variety of different hypotheses to be tested. Further, this course design allowed students at large institutions to have a more personal, hands-on experience. This laboratory was developed for 120 students meeting during the same three hour block.

Here, we describe experimental materials provided for the four laboratory components. For the first laboratory focusing on the structure and function of poly (methyl methacrylate) commonly used as bone cement, available reagents included methyl methacrylate polymer with an initiator, methyl methacrylate monomer with an initiator, a variety of additives including salts, metals, wires to change biomaterial properties as well as silicone molds to make the test samples, and weights and clamps for an inexpensive deflection test. (All materials are available from Fisher.) The second laboratory about swelling properties of hydrogels provided students with alginate solutions of different concentrations (RPI), different salt solutions for physically crosslinking of the alginate (Carolina Biological Supply), and different swelling solutions (varying pHs and tonicities) for testing the hydrogels ability to swell depending on experimental modifications, scintillation vials, and scales so that students were able to calculate the swelling ratio. The third lab investigating metal toxicity included brine shrimp (Carolina Biological Supply) and different forms and types of metals (including Cobalt chloride, Nickel chloride, Cobalt and Nickel particles, as well as stainless steel and Titanium spheres available from Sigma and McMaster-Carr). The final lab component exploring cell adhesion on different substrates commonly used in biomaterials and biological research included the following reagents: fibroblasts (kindly donated), glass coverslips, culture materials (RPI, BioWorld, Sarstedt), poly L-lysine (Fisher), and gelatin (Sigma). In this lab, students also explored hydrophobicity and hydrophilicity of different surfaces using a goniometer.

To assess this intervention, a mix method approach was adopted, including faculty vignettes, a student value survey assessed for validity and reliability, and analysis of class data with respect to persistence and achievement. More specifically, the student value survey to be given at the beginning and end of the semester will be validated using factor analysis and tested for reliability using Cronbach's alpha.

Results: Total costs per student for the four modules was less than $35 per student. More specifically, each module cost less than $15, $5, $5, and $10 per student respectively. Examples of hypotheses for each of the modules are as follows: In lab module 1, students hypothesized that inclusion of salt additives would affect the Young's modulus of poly (methyl methacrylate). In lab module 2, students hypothesized that acidic swelling fluid would result in less swelling than more neutral swelling fluid using research studies linking hydrogels for drug delivery to physiological pHs. For lab module 3, students hypothesized that Cobalt particles would be result in higer levels of toxicity than Nickel particles. Finally, in lab module 4, students hypothesized that gelatin and poly L-lysine would increase cell adhesion as compared to glass coverslips. Laboratory handouts, list of materials, and student value survey are available through the authors. Overall, instructors observed increased student engagement in a team-based setting, critical thinking, and responsibility for learning. The laboratory will be assessed using the student value survey at the end of the semester. Further, scores and attendance data will be used to assess achievement and persistence in this inquiry-based introductory biomaterials laboratory.

Conclusions: This four-module, inquiry-based laboratory is not only sustainable due to low cost and time requirements but also adopts the evidence-based practice of inquiry-based instruction.

References:

1. Lee, V.S., ed., Teaching and Learning through Inquiry, 2004
2. Prince, M. and Felder, R. JEE, 2006; 95: 123-138.