# Undergraduate Design and Structure-Property Characterization of Biomaterials

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**Statement of Purpose:** The clinical need for biomaterials will require educational institutions to provide specialized instruction in these areas (Black J, Journal of Applied Biomaterials 1992;3:231-6). In fact, biomaterials is one of the twenty-three core topics within bioengineering identified by the Vanderbilt, Northwestern, Texas, and Harvard-MIT (VaNTH) Engineering Research Center (ERC) funded by NSF. Notably, VaNTH ERC established a taxonomy, or list of core competencies, within the area of biomaterials that educators should cover. On this list of core competencies are i) the fundamentals of materials science, ii) methods of characterizing material properties, and iii) polymer synthesis and characterization. Yet, existing educational modules related to biomaterials tend to focus biological performance and evaluation. In this paper, we discuss a hands-on laboratory activity that is materials-centered and applicable to a range of student levels and STEM disciplines. The activity teaches students fundamental principles of structure-property relationships, and also develops skills related to chemistry, data acquisition and analysis, and experimental factorial design.

**Methods:** Students polymerize a solution containing the photo-initiator dimethoxy propyl acetophenone, the cross-linker poly (ethylene glycol) (PEG) dimethacrylate, and monomer methacrylic acid (MAA) to produce pH sensitive poly (MAA-g-EG) hydrogels as previously described (Tuesca A, Journal of Pharmaceutical Sciences 2008;97:2607-18). Formulations were prepared with a range of monomer concentrations (40 and 75 wt% total monomer in solution) and with a high and low crosslinker amount (0.4 and 2.0 wt%), thus a $2^2$ factorial design was used. The hydrogels were swelled in phosphate buffered saline at 37°C for three hours prior to tensile testing (Shimpo mechanical testing system). Pre and post-tests were used to gauge student mastery of learning outcomes set forth by ABET for undergraduate chemical engineers (Table 1). Pre and post-test questions were aligned to these outcomes. Scores were analyzed with a t-test and a 95% confidence interval (alpha = 0.05).

**Table 1. Pre- and post-module assessment questions alignment to ABET outcomes for undergraduate chemical engineering students.**

| Outcome | Measurable skills categorized within this outcome: |
|---|---|
| An ability to apply knowledge of mathematics, science, and engineering (ABET-A) | Successfully apply fundamental concepts of chemistry, material science, and transport phenomena to biomaterial science and drug delivery systems. Identify variables that define mass transfer and structure-property relationships. |
| An ability to design and conduct experiments, as well as to analyze and interpret data (ABET-B) | Experience with the preparation and mechanical characterization of a polymeric hydrogels will develop student ability to identify key structural variables, analyze data, and evaluate significance. |

**Results:** The laboratory was piloted in two courses at Rowan University, the senior level elective Biomaterials Engineering (21 students) and Freshman Engineering Clinic (18 students). Both courses include a weekly 2.5-hour time block into which laboratory activities can be incorporated. At the freshman level, students were given pre-prepared hydrogels, which were tested under tension in acidic and neutral medium. Students correlated the pH-dependent changes in network structure with the tensile properties, which has been reported previously (Nakamura K, Journal of Controlled Release 95;95:589-99). The senior-level students prepared the formations with $2^2$ factorial design to learn the effect of crosslink density and polymer content. Pooled data from the two classes is shown in Figure 1. For ABETA/ and ABET B, the percentage of correct responses increased by 39 and 35%, respectively, between the pre-test and the post-test. The increase for ABET B was statistically significant ($p<0.05$).

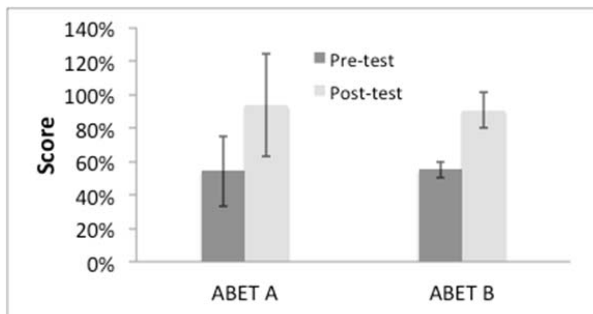


**Figure 1. Percentage of correct responses for each learning outcome as described in Table 1.**

**Conclusions:** Pre and post-test results indicate that the laboratory activity contributed to ABET outcomes A and B for undergraduate chemical engineering students. In current work, the experiment is being extended to use the results of the tensile testing to calculate the network mesh size as a function of pH, crosslinker amount, and monomer concentration. Furthermore, the release properties of the gels will be characterized as a function of these parameters.

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