A Hypothesis-Driven Tissue Engineering Lab Course for Undergraduates
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Introduction
The Department of Bioengineering at UCSD introduced a tissue engineering (TE) lab course as an elective for upper division undergraduate students in 2007. The course objectives were (1) to train students in skills beneficial for employment or advanced studies in TE and related fields and (2) to improve students’ abilities to plan and conduct experiments.

Materials and Methods
The 10-week course, BENG167, met once a week in a single 4-hr block. Instruction began with basic cell culture and biohazard safety training followed by 4 2-week experiments. For each experiment, teams of students were given reading, a list of available materials and equipment, general lab protocols, and an experimental objective. Teams formulated a testable hypothesis, wrote a detailed protocol, and briefly met with either the instructor or a graduate assistant to review and modify their protocol to maximize the probability of success.

An overview of each experiment follows:

Cell Seeding: Student teams were challenged to devise a protocol for optimal seeding of cells onto a scaffold. Materials and equipment were provided for static seeding and dynamic seeding using either a spinner flask or an orbital shaker.

Cell Migration: Teams developed a hypothesis related to cell migration in response to a chemoattractant that would be testable using an under-agarose migration assay.

Scaffold Fabrication: Teams were challenged to design and implement a method for fabricating a scaffold in any clinically relevant geometry using the general strategy of lyophilization of a collagen solution within a mold.

Phenotype Modulation: Teams developed a testable hypothesis related to the effects of culture conditions on chondrocyte phenotype, characterized by glycosaminoglycan production. Experimental variables included culture configuration, density, media formulation, etc.

Student feedback was collected using a campus-wide course evaluation system. Results from BENG167 and other bioengineering labs offered during the same academic years were compared.

Results
Standard course evaluation forms ask students to rate (on a scale of 1 to 5) their agreement with statements related to course quality and to indicate whether they recommend the course overall. Key results from BENG167 and other lab courses are summarized in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>BENG160</th>
<th>BENG162</th>
<th>BENG172</th>
<th>BENG167</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enrollment</td>
<td>49±8</td>
<td>50±19</td>
<td>95±8</td>
<td>10±6</td>
</tr>
<tr>
<td>% Recommend</td>
<td>96±0.1</td>
<td>73±0.3</td>
<td>97±0.0</td>
<td>96±0.1</td>
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<tr>
<td>I learned a lot</td>
<td>4.0±0.2</td>
<td>3.8±0.5</td>
<td>4.4±0.0</td>
<td>4.5±0.8</td>
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<tr>
<td>Was difficult</td>
<td>3.2±0.1</td>
<td>3.2±0.0</td>
<td>4.2±0.1</td>
<td>3.2±0.2</td>
</tr>
<tr>
<td>Material was intellectually stimulating</td>
<td>4.1±0.1</td>
<td>3.8±0.3</td>
<td>4.5±0.1</td>
<td>4.6±0.4</td>
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</table>

Table 1. Student evaluation of lab classes from the 06-07 and 07-08 academic years; BENG160: Chem & Mol Bioeng Tech, BENG162: Biotech Lab, BENG172: Bioeng Lab, and BENG167: Tissue Eng Lab. Ave±SD, n=2.

Student comments were very positive and demonstrate that course objectives were met. Specific comments included: “Great to be able to learn how to make and alter experiments” and “Yay! More techniques to add to my resume!”.

Discussion and Conclusions
Student feedback indicates that BENG167 was as enjoyable, effective, and interesting as more established courses. Students did not find the open-ended experiments particularly difficult, suggesting that more complex problems can be tackled in the future. Class size was intentionally small during development but more students can be accommodated by running all the experiments concurrently. The success of BENG167 demonstrates the feasibility and benefits of a hypothesis-driven TE lab course.

Disclosures
There are no conflicts of interest to disclose.