Development of Hands-on Modules for Cellular Bioengineering

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Abstract

Innovation: Utilized a problem-based learning approach to develop four hands-on modules to be used in the Cellular Bioengineering class.

Goals:

1) Establish a high-quality learning environment that promotes students' engagement and learning.
2) Utilize the problem-based learning lab modular experiences to promote teamwork where students learn from each other as well as teach one another.

Results: The modules developed were implemented as a part of the Cellular Bioengineering course twice. Results were presented in the ASEE 2011 meeting and were published in the meeting's proceedings.

Challenges: 1) No lab space, 2) no course credits for the modules and 3) very small budget to work with.

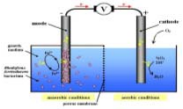
Pedagogical topic: Project-Based Learning.

Introduction and Objectives

Introduction: Well trained cellular bioengineers can contribute to many biomedical and environmental problems[1]. Despite that, most cellular bioengineering courses offered nation wide are largely theoretical[2].

Tissue engineering
rcsed.ac.uk

Bioremediation
inhabitat.com



Microbial fuel cell
isdsclass.bus.isu.edu

1) Clase, K. L. et al. Adv. Physiol. Edu. 2008, 32, 256-260.
2) Daymond, J. S. et al. Genetics, 2009, 181, 13-21.

Discipline and courses: Bioengineering, Cellular Bioengineering classes (BE 350 and BE 550).

Objectives:

1. Reinforce and illustrate basic cellular engineering principles in the minds of students.
2. Familiarize students with necessary skills needed to work with cells safely and with equipment available in cellular bioengineering laboratories.
3. Improve students' design, critical thinking and trouble shooting skills through an inquiry-based learning approach.
4. Train students in technical report writing and improve their teamwork abilities.
5. Expose students to real-world problems.

Developmental History of Innovation

1. Need for a wet cellular bioengineering lab experience in our curriculum.
2. Even in curricula were labs are offered, traditional approach where students perform prescribed. experiments with little critical reasoning is used[3].
3. In 2008, modules were optimized in my research lab.
4. In 2009, one module was implemented in BE 350 class.
5. In 2010, four modules were implemented .
6. More modules are to be designed in the near future.

3) Felder, R. M. et al. Proceedings of the ASEE 1988 conference, section 2413.

Learning Activities and Materials

Module 1: Diffusion across a cellular membrane

Goal: To enhance students' understanding of passive diffusion through the quantification and modeling of transport across a cellular membrane.
Concepts covered: Fick's law of diffusion, tonicity of solutions inside and outside the cell, osmolarity, selectivity & transport mechanisms (Figure 1).
Design: The module allowed students to:
1) Observe osmosis in action; 2) test whether the diffusion process is reversible; and 3) test whether larger molecules can cross the cell membrane.

Module 2: Bacterial growth in batch bioreactors

Goal: To quantify the kinetics of bacterial growth as a function of environmental stresses.
Concepts covered: kinetics & phases of bacterial growth.
Design: Non-pathogenic, bio-safety level 1 *Listeria welshimeri L40* bacteria were used in the module. This module allowed students to learn how to: 1) sterilize media and reactors; 2) quantify the effects of physical (ionic strength), chemical (pH) or biological (nutrients) stresses in bacterial growth kinetics (Figure 2).

Module 3: Transport in saturated porous media

Goal: To quantify the effects of different factors in the transport of bacteria in saturated porous media.
Concepts covered: 1-dimensional colloidal transport and filtration theory.
Design: The module allowed students to: 1) grow bacterial solutions of a non-pathogenic *Listeria monocytogenes*, 2) select variables to investigate such as the rate , salinity and concentration of bacterial solution fed to the column, column and collectors' physical dimensions, type of the collector (sand versus glass) & direction of flow and 3) collect breakthrough curves (Figure 3).

Logan, B. E. et al. J. Envion Eng ASCE 1995, 121(12), 869-873.

Module 4: Enzyme Kinetics of Glucose Oxidation

Goal: To model glucose enzyme kinetics.

$$\text{Glucose + ATP} \xrightarrow{\text{Hexokinase}} \text{Glucose-6-Phosphate (G6P) + ADP}$$

$$\text{G6P + NAD} \xrightarrow{\text{G6PDH}} \text{6-Phosphogluconate + NADH}$$

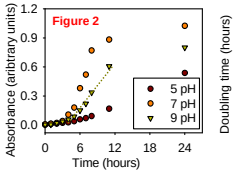
Concepts covered: Michaelis-Menten enzyme kinetics, statistical analysis and modeling techniques.
Design: The module allowed students to: 1) choose a range of glucose concentrations and time intervals to investigate; 2) mix reactants; 3) measure products' concentrations and 4) quantify the Michaelis-Menten kinetic parameters (Figure 4).

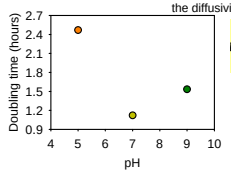
Figure 1: Raw (R) and hardboiled (B) eggs after 24 hours of incubation in water (1), syrup (2) and energy drink (3).

Fick's law

$$j = -DA\frac{\Delta C}{\Delta X}$$

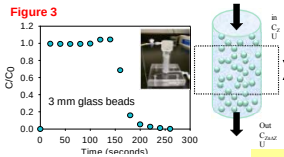
Where: j is the molar flux, A is the diffusion area, ΔC is the concentration gradient across cell membrane, Δx is membrane thickness and D is the diffusivity.





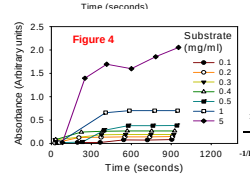
$$t_d = \frac{\ln(2)}{\mu}$$

T_d: Doubling time
μ: Specific growth constant (hr^{-1})
1st order kinetics



$$\frac{C}{C_0} = \exp\left[-\frac{3}{2}\frac{1-\theta}{d_c}\alpha\eta L\right]$$

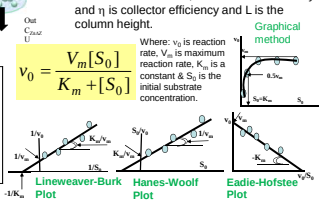
Where: C and C_0 are the output and inlet bacterial concentrations, θ is porosity, d_c is the collector diameter, α is collision efficiency and η is collector efficiency and L is the column height.



$$v_0 = \frac{V_m[S_0]}{K_m + [S_0]}$$

Where: v_0 is reaction rate, V_m is maximum reaction rate, K_m is a constant & S_0 is the initial substrate concentration.

Graphical method



Execution

1. Implemented in the Introduction to Cellular Bioengineering undergraduate and graduate courses (BE 350 and BE 550).
2. In 2009, 8 students & in 2010, 13 students
3. Due to the small class size, modules were executed in my research lab.
4. $1000 budget was given in 2010.
5. Students did not like working outside of class schedule.
6. Implementing modules required a lot of my time as well as my TA's time because each group of students will run each module on a different day.

Major Issues to Resolve

1. Add a one credit hour to the course to develop a stand-alone cellular bioengineering laboratory.
2. Identify a space to host the lab course.
3. Apply for a grant or several grants to secure funding to establish a lab with needed equipment (NSF *Transforming Undergraduate Education in Science* grant).
4. Think of ways on how to incorporate cellular engineering experiences throughout the curriculum.
5. Train students on handling cells safely.
6. Revise modules to have them finished within a four hours lab period.
7. Optimize modules to improve critical thinking skills of students.
8. Think of ways to relate modules to real-life problems.
9. Develop four additional hands-on modules.

What you hope to learn at FOEE

I hope to learn about how to:

1. Apply new pedagogies in my classroom to improve students' learning.
2. Adapt new innovations and effective teaching practices in my classroom based on experiences of others.
3. Equip students with necessary skills needed to prepare them to lead interdisciplinary careers .
4. Use active learning in the classroom to improve students' retention of knowledge.
5. Implement assessment techniques to ensure that the educational outcomes are met.
6. Improve my teaching innovations.
7. Disseminate my innovations to other colleagues who will be welling to give them a try in their courses.
8. Collaborate with my colleagues in future proposals.
9. Improve students' performance in class.
10. Learn about my colleagues research topics and teaching innovations.

Discussion

Implementing the modules was successful based on the results of the following assessments:

1) The overall assessment of the course which was completed by 64% of students and yielded a 4.67/5.0 rating for the course . Students enjoyed the flexibility of the modules and commented that the modules were very helpful in reinforcing specific concepts in their minds.
2) The good grades of the technical reports written by students. Grades were based on a rubric shared with students prior to assignment.
3) The results of a voluntary in-class survey conducted after all modules were performed. Students agreed that the lab was beneficial in reinforcing some of the concepts discussed in class in their minds and working in teams helped them in running the experiment better, learn from each other and have better communication skills.

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Students who optimized modules

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