

Multimedia Assisted Instruction in Upper Level Engineering Courses

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Introduction

With significant fundamental advances in biosciences, increasing number of products, particularly pharmaceuticals, are manufactured using biological agents. New applications of genetic engineering in many industrial segments are reported at a seemingly increasing rate. Consequently, a larger number of engineers of tomorrow would need to be familiar with the fundamental precepts of applications of biosciences, genetic engineering. The specific applications include manufacture of both diagnostic and therapeutic proteins using recombinant or natural cells. Because these applications have a significant manufacturing component, it is a natural extension for chemical engineering students.

The central idea in the Engineering Biotechnology course is to treat within a single course all significant scientific and engineering issues that encompass converting genes, the starting material, to a final product that is manufactured for the market place. In our view, it is important to tell the whole story in a single course with sufficient depth so that the relevancy and significance of the emerging area of biotechnology can be communicated effectively. To assist us in covering a broad topic area, we resorted to binding the topic thematically and also developed a self standing multimedia lectures which are distributed on a CD ROM.

Traditionally the concepts covered in Engineering Biotechnology course would be developed over many courses, biochemistry, cell biology or cell physiology, genetic engineering, biotransport phenomena, bioprocess engineering and unit operations. Although the current course does not cover the same material to the depth possible in the traditional courses, it does provide an engineering student with an important overview, and equip him with tools to pursue further study in biotechnology. The course builds upon the biological and engineering principles introduced in the Freshman course called, Chemical and Biological Foundations of Engineering. Because the material is organized on a topic relevancy basis and the style of instruction is 'lateral' rather than 'pyramidal,' the

biological principles and engineering science can be commingled to provide a complete picture.

Rationale

To make a cohesive course illustrating the topic areas of genetic engineering, manufacturing and drug administration, we chose a thematic approach. Such an approach offers the advantage of integrating fairly diverse, yet connected, topic areas. We were determined from the start that the integrated course should avoid a survey-course flavor in its content. Among the various themes explored, we decided on the product theme, insulin. This theme has several advantages, including student familiarity and that it requires a biological manufacturing system. Other products considered were penicillin, granulocyte stimulating factor, interferon and others. Insulin is the first product of genetic engineering that was commercialized on a large scale and a fair amount of open literature is available on its manufacture. Although cloning strategies used for insulin is non-trivial, the processing steps that follow the biological step offered a good engineering balance.

The course was organized into four segments: insulin and genetic engineering, manufacture of insulin in bioreactors, delivery of insulin in the human body and biosensors. The course was team taught by four instructors whose teaching and research background corresponds to the four topic areas. In the first edition of the course, the three non-lecturing instructors attended all the classes so that transition from topic to topic would be smoother. Additionally, availability of all four instructors in each class meeting enabled answering of certain student questions complete. The attending instructors provided important feedback with comments and suggestions to improve learning in the class room.

Gateway Coalition

The Gateway Coalition ⁽¹⁾, funded by the National Science Foundation, is intended to open new avenues for learning by altering engineering education from a focus on course content to the development of human resources and the broader experience in which individual curriculum components are connected and integrated. The scope of the program includes four major parts: curriculum structure; human potential development; instructional technology and methodology; quality assurance and evaluation measures. The current course in Engineering Biotechnology is being developed through Gateway Coalition.

The Gateway Engineering Education Coalition includes ten institutions, namely, Case Western Reserve University, Columbia University, Cooper Union, Drexel University, Florida International University, New Jersey Institute of Technology, Ohio State University, University of Pennsylvania, Polytechnic University, University of South Carolina.

Multimedia Development

An Authorware based software was developed over the past two years. The main parts of the course was recorded and appropriate graphics, imagery and animation were designed and integrated with the recorded lectures. Care was taken to capture the essential ideas for incorporation into a self standing "animated lectures". There are three virtual labs on the topics of oxygen transfer in bioreactors, cell growth and yield determinations available as virtual labs. These simulations enabled the student to move knobs and sliders to change settings of a process equipment and then observe the consequence of such changes through process response. Using suitable analysis, the student was asked to determine a process characteristic.

A beta version of the software on a CD ROM was distributed to students in Winter 1996/7 along with the offering of the course. Both PC and Macintosh versions were distributed.

Engineering Biotechnology and Drexel Curriculum

Over a seven-year period, Drexel University has focused on major curriculum reform in undergraduate engineering education through the effort of E⁴ and Gateway programs⁽¹⁻³⁾. Initially, attention was directed to the freshman and sophomore years via the E⁴ program ^(1,2). This was not a simple repackaging of courses, but a major reconstruction with faculties from the College of Engineering and the College of Arts and Sciences working together to develop an integrated lower division curriculum for all engineering

students. In the upper division curriculum, all engineering students will have the option of electing one or more from a choice of five interdisciplinary courses which address such areas as materials, biotechnology, environment, energy and communications. The Engineering Biotechnology course described in this paper is expected to be an integral part of the new Drexel Curriculum as a pre-junior/junior technical elective open to all engineering students.

Course Offering of Engineering Biotechnology

The course was offered for the first time in a lecture format during Winter quarter of 1994-95. Twenty-three students, most of who were seniors in chemical engineering, took the course for credit. Six other students, mostly graduate students, also attended the lectures. A second, slightly revised version was offered again during the Spring quarter of 1995-96 and the most recent one with the addition of the multimedia CD ROM in Winter quarter of 1996-97.

The biological material in particular was quite new to most of the students and seemed to present the most difficulty. Homework problems and class discussion of how to go about gene manipulations were used to help overcome these problems. A short text on genetic engineering was used during the second offering of the course to provide students with an immediately available reference source. Instructors made use of assigned problem sets to give the students experience in the practical issues that arise in planning gene cloning, scale-up of fermentations, drug distribution in the body and biosensor operation. Thus, students were able to make the connection between such things as rate equations used in biological systems and those encountered previously in their engineering courses. Another useful approach was to briefly summarize previous class materials at the beginning of each session.

Course Content

The course was open to all senior engineering students as a three quarter-credit technical elective. When students of the new Drexel Curriculum will need cross-disciplinary electives, we anticipate offering this course as a Junior-level elective. Until then, Engineering Biotechnology will be offered as a Senior elective because of our curricula's constraints. The course was team taught by a team of instructors, three chemical engineering and one bioscience faculty member. A brief course outline is given in Table 1.

The course was organized into four main sections: principles of genetic engineering, bioprocess engineering, drug delivery, and biosensor. Each section was taught by a single instructor. The genetic engineering section introduced insulin physiology, cloning methods, as well as gene transfer, expression, and regulation. Topics presented in the bioprocess engineering section were fundamental

stoichiometry and thermodynamics of growth, design of high cell density reactors, separation and purification of insulin, manufacturing methods and GMP/FDA regulations. The drug delivery segment covered relevant protein properties, pharmacokinetics and dynamics, and insulin and other drug delivery methods. The biosensor module introduced fundamentals of sensor technology, the role of biomolecules, sensor design methods, and glucose sensing in medicine and bioprocesses.

Evaluation

The purpose of evaluation was to provide useful feedback on the course as well as to determine the impact the course was having on the students. We employed six strategies for evaluation: Each student was required to complete a short weekly journal, the teaching faculty and the teaching assistant met weekly to discuss the journal entries and general strategy, all faculty and the teaching assistant attended all lectures, lectures were videotaped, an end of term evaluation sheet was distributed to the students, and an external evaluator was employed.

Table 1 Course Content

Week 1: Introduction, Insulin Physiology & Introduction to Cloning

Week 2: Cloning, Identifying insulin gene & DNA amplification

Week 3: Gene transfer, expression and regulation, Stoichiometry and thermodynamics of growth.

Week 4: Design of High cell density reactors, Cell separation & disruption. Insulin Recovery

Week 5: Good Manufacturing Practice & FDA Regulations, [Mid Term 1]

Week 6: Protein properties relevant to drug delivery, Pharmacokinetics and dynamics: Insulin & others

Week 7: Insulin delivery requirements - strategies, Controlled release mechanisms & methodology

Week 8: Glucose sensing: application in insulin delivery, Detection methodology for *in vitro* applications.

Week 9: Use of biomolecules for sensing. [Mid term 2]

Week 10: Design of biosensors for *in vivo* applications, Review & Evaluation, Interview with Evaluator

Comments from weekly journals indicated that initially the students were somewhat uncomfortable with biological principles and the lack of a text book. The students felt more comfortable with engineering problems. Many were complementary of the faculty effort, despite any difficulties with the course. Some who expressed concern with the biology segment, later appreciated the value of fundamental science and its relevance to the topic. Many appreciated that the engineering principles that they have learned to date can be used in such "far-out fields" as biotechnology. Almost all said that the course contained more than they could digest. Similar results were obtained by the end of the course review.

The external evaluator conducted post-course interviews with faculty and students as well as reviewed journals, the video and course materials and submitted a report analyzing various factors of evaluation. From the student perspective she came to conclusions similar to ours, namely: biological terms were new and confusing, a sense of unease with the lack of a text book, increased comfort level as course progressed, a supportive Teaching Assistant and outside tutoring were of great help. Student suggestions for improvements included: Use of a text book, addition of a laboratory, continuous reviews to tie topics together, learning through more problem solving. From the faculty perspective she was impressed with the very positive attitude about goals and rationale. Her specific suggestions included the following. Frame the course more explicitly for the students so that students become more aware of the innovative nature of the course and what they will need to do to participate more effectively. It was also suggested that the writing of weekly journals should become a part of learning by use of specific questions that allow for in-depth processing, reviewing, as well as clarifying concepts. Invite representative students to the weekly instructor's meetings, add a laboratory component, put reading and background materials together as a text, add an essay or work of fiction to provide deeper understanding of underlying issues and values.

Impact of Multimedia

The students were queried as to the advantage of the multimedia as a support to the class room instructions. About a third of the students said that they were not able to use the CD effectively because their home computer did not have CD drives or that its speed was too slow. Of those who did have access to sufficient hardware capability, almost all of the students responded positively that the CD was of tremendous assistance understanding of concepts. They specifically refer to animations as being their favorite. Almost all the students praised the effort of the faculty team and took particular note of the virtual lab which offered interactive learning opportunities.

Future Directions

As described above, engineering students found 'descriptive' biology difficult to master as they are used to learning by the problem solving method. Second, lack of 'biological' experience lead to difficulty in mastering genetic engineering concepts. Therefore, two main focus of activity in the future will be to revise the course material to teach biological fundamentals through a problem-solving approach and to develop a "virtual" lab for enhanced learning.

Developments of a module in bioseparations to augment the manufacturing segment is taking place at another Gateway site, Columbia. A learning module on Good Manufacturing Practice and FDA regulations is also expected to be developed.

References

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Inquiries and Additional Information

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The text book developed for the Engineering Biotechnology course is available in a browsable form at

<http://www.chemeng.drexel.edu/Pages/front.htm>