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Integration of the "How People Learn" Framework into Educational Module Development and Implementation in Biotechnology

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Abstract- A team of domain experts, learning scientists, learning technologists, assessment experts and students are currently working on developing and refining educational tools for biotechnology as well as for other domains within the "How People Learn" framework in the NSF funded VaNTH ERC in Bioengineering Educational Technologies. Educational modules in biotechnology cover a collection of challenges designed around bioreactors, mass and momentum transfer issues, and microbial kinetics, which are among core biotechnology topics. The activities form the core of the STAR Legacy Cycle method that was adopted as the template for module development. These modules have been tested in classrooms both at Vanderbilt and Northwestern and detailed assessment data have also been collected. The focus of this contribution is on development and implementation of these educational modules at two universities (VU and NU).

Keywords - Educational tools, Challenge-based learning, Biotechnology education

I. INTRODUCTION

Biotechnology is one of the active domains in NSF funded VaNTH (Vanderbilt, Northwestern, University of Texas, and Harvard/MIT) Engineering Research Center in Bioengineering Educational Technologies. Bioengineering faculty are currently working with learning scientists from schools of education, learning technologists from computer sciences/engineering, assessment experts from school of education and students to develop educational modules for bioengineering education. Such educational tools are intended to enhance the learning experience of students, support collaborative and reflective learning, and provide opportunities for students to practice skills expected in engineering practice.

The focus of this paper is on the development and implementation of educational modules and related activities in the domain of biotechnology. It also addresses how these modules and the activities map to the learning goals of these modules.

II. EDUCATIONAL MODULES

A. The "How People Learn" Framework

The modules were centered on the "How People Learn" Framework [1]. Basically, it contained four primary elements:

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- (i) *Learner-centeredness*: That is, the environment and class activities should take into account the knowledge, skills, preconceptions and learning styles of the learners.
- (ii) *Knowledge-centeredness*: In the sense that it helps students learn with understanding by thinking qualitatively, and organizing their knowledge around key concepts.
- (iii) *Assessment-centeredness*: Such that it provides frequent opportunities for students to make their thinking visible so that their understanding can be refined as needed.
- (iv) *Community-centeredness*: In the sense that it fosters norms that encourage students to learn from one another, plus encourages faculty to do likewise.

Each module included a *Challenge*, methods to stimulate *Idea Generation*, presentations of *Multiple Perspectives*, questions and materials to support *Research and Revision*, opportunities to *Test Your Mettle*, and methods to *Go Public*, and hence it followed a pedagogical method called a "Star Legacy" sequence (Figure 1) [2].

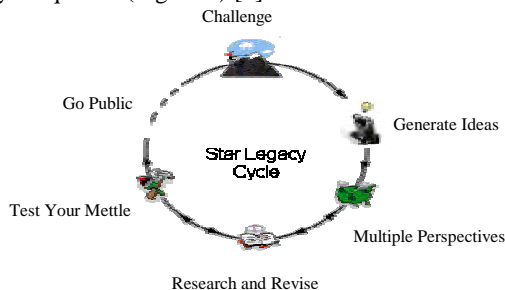


Fig. 1. Star Legacy Cycle

B. Learning Objectives and Implementation

Three educational modules were integrated into class material at Vanderbilt and Northwestern: The first two modules covered bioreactor operations and were originally developed by T.D. Giorgio and S.P. Brophy at Vanderbilt [2]. The first one (M1) focused primarily on bioreactor choice and the second one (M2) focused on mass and momentum transfer issues in bioreactors. The third one (M3) was a module on microbial kinetics that is under development by G. Birol and A.F. McKenna at Northwestern [3]. The topics to be included in the modules were carefully chosen to insure coverage of a significant portion of the taxonomy. Each module required from three to five 75-minute classroom sessions and included activities between sessions.

Learning objectives of the first two modules (M1 and M2) were to: classify bioreactor types; explain the major differences among various bioreactor types and recognize the constraints of bioreactors; learn the different types of cell cultivation; recognize the constraints for cultivation of

different cell types; be able to choose the right bioreactor configuration for a given cell culture conditions; learn the operation and analysis of bioreactors; and learn the mass transfer limitations in bioreactors.

Learning objectives of the third module (M3) were to: explain how and why cell, product and substrate concentrations change in batch cultures; learn what the specific growth and the specific product formation rates are; define rate expressions for cell growth, and for product formation given the growth conditions; explain the differences in rate expressions for cell growth and for product formation; recognize the limitations of growth, of product formation; demonstrate the ability to write down a rate expression for a given data set and to solve it; compute the specific growth rate and the specific product formation rate; demonstrate the ability to combine cell growth and product formation data to find substrate utilization.

Currently, these modules are being used in biotechnology courses at VU and NU for testing their effectiveness. Learning objectives of the modules aligned with the learning objectives of the two courses offered at VU and NU. The topics covered in these courses and how the educational modules were embedded into class material were as follows:

VU BME 281 Biotechnology

1.0 *Biology of eukaryotic cells*

2.0 *Manipulating the gene in cells*

2.1 *Gene cloning*

2.2 *DNA sequencing*

2.3 *Expression systems*

3.0 *Ethics of biotechnology*

4.0 Mammalian cell bioreactors (M1 and M2)

4.1 Mass transfer

4.2 Momentum transfer in mixing

4.3 Fluid stress and cellular collisions

4.4 Scaling up the laboratory bioreactor

5.0 *Mammals as bioreactors*

6.0 *Hybridization for detection*

6.1 *Microarray technology*

7.0 *Gene therapy*

7.1 *Intracellular aspects of gene delivery*

NU BME 395 Special Topics

1. *Cell Biology*

2. Bioreactors (M1 and M2)

2.1. Cell Cultivation

2.2. Operation and Analysis

2.3. Mass Transfer Limitations

3. Microbial Kinetics (M3)

3.1. Stoichiometry of Growth

3.2. Biomass Formation

3.3. Product Formation

3.4. Substrate Utilization

4. *Product Recovery*

4.1. *Recombinant DNA Technology*

4.2. *Separation of Insolubles*

4.3. *Initial Isolation*

4.4. *Primary Purification*

4.5. *Final Purification*

Text in **bold** shows the topics that map to the content of these modules.

In order to assess the achievement of the learning objectives of the courses (VU and NU) and the modules (M1, M2 and M3), a series of assessment methods were applied and were described elsewhere [4]. Briefly, there were three levels of assessment: (i) course as a whole which was achieved by pre/post tests, (ii) module specific assessment which included surveys, (iii) assessment of learning objectives which included homework, two take home examinations and class participation. Learning objective specific rubrics were also developed to analyze the assessment data [4].

III. SUMMARY

Educational modules were designed by systematically linking learning resources together based on pedagogical principles defined by current learning theory [5]. To insure the success of these modules: First, the modules were built by domain and assessment experts and learning scientists based on taxonomy, and needs of the course(s). Second, they were delivered to learners for classroom testing and surveys were collected for evaluation. Third, the material was refined based on learner's input. Fourth, classroom testing took place again [5,6].

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