A Distance Education partnership between Villanova and IT Sligo in Graduate Biochemical Engineering

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Recently, Ireland has become a hotbed of research and manufacturing in the Pharmaceutical Industry. A unique partnership was created betweenVillanova and IT Sligo (Ireland), whereby Irish graduate students pursuing an MS in Biopharmaceutical science and Villanova graduate students pursuing an advance engineering degree can take two Villanova classes together via Distance Education (DE) technology. These two classes focus on upstream and downstream bioprocessing, and cover engineering topics such as the design and operation of bioreactors, centrifuges and chromatography systems as well as biology topics such as cell structure and metabolism and genetic engineering. This allows for technical exchange that is cross-cultural, and like what they would experience on industrial teams that are now interdisciplinary and global. This presentation will highlight the challenges and benefits of this new program. The benefits include exchange of technical perspective that occurs due to interaction on team projects, and the challenges range from following US export laws when registering students to communication through different time zones to teaching both scientists and engineers together.

Introduction

Globalization is changing the way in which engineering work is organized and in which companies acquire innovation. For example, the new Boeing 787 reportedly has 132,500 engineered parts that are produced in 545 global locations. Companies no longer just look within themselves for innovation, nore do they just purchase it by acquiring smaller companies. Today they obtain innovation wherever it is found, including in other companies and in other countries[1]. A global awareness is required of entrepreneurs, in order to assess potential worldwide impact of or market for their innovations[2]. In highly regulated industries such as the pharmaceutical business, it is essential for engineers designing the products and processes to be aware of the different regulatory legal guidelines worldwide[3] and the technical and cultural challenges associated with relocating manufacturing and research facilities from the US to countries such as Singapore, India and Ireland[4].

One of the goals of the college of Villanova's college of engineering is to produce engineers that have sufficient global awareness to be able to immediately contribute to and eventually lead industrial and academic teams that these days function across companies, countries and continents. This goal is in line with those put forth in a recent publication of the National Academy Press called "Educating the Engineer of 2020"[5]. To accomplish this, undergraduate students are encouraged to pursue as electives courses that train them in other languages and teach them about other cultures and consider study abroad and service learning opportunities. Graduate students has less opportunity for this type of development and training, but often do get exposure to other cultures through social interactions with fellow students, many of whom in engineering reside in another country or have lived or worked in other countries. Distance education (DE) is clearly another way to provide students with cross-cultural or global experiences. How such a classroom could be run to ensure that DE students have an opportunity to interact with each other sufficiently is a question that has not been explored much in the current educational literature.

Villanova University has a state-of-the-art distance education delivery platform, and a collection of graduate biochemical engineering classes that are highly regarded by part-time and full-time students for there effective balance of theory with practice as well as biology with engineering. Consequently, Villanova was a well-suited partner for IT Sligo in Ireland who has assembled a Master's of Science (MSc) DE program in Pharmaceutical Science but was lacking modules in biochemical engineering. This relatively new Sligo MSc program is attracting some of Ireland's best young scientists and engineers who are interested in or currently working in the growing pharmaceutical industry over there. The purpose of this paper is to describe the some of the benefits and challenges associated with a new partnership that allows IT Sligo students to take two of Villanova's graduate biochemical engineering courses.

The DE delivery capabilities at Villanova

Villanova University's College of Engineering is at the forefront of this trend in its award winning distance education program. The program was instituted in 1997 on a class by class basis. Since then the program has evolved to provide five complete online graduate degree programs as well as numerous individual stand alone graduate and undergraduate online classes. The College has three world-class distance education classrooms that have allowed it to offer master's degrees fully online with the latest technology. The format of the distance programs allows students and instructors to interact in real time through the use of video teleconferencing and call in capability as well as posting questions via instant messaging to the professor as the class is happening. The audio, video and VGA content is packaged and presented to the viewer in a seamless unit that translates into a learning environment that rivals and in some ways surpasses the traditional classroom model. The online program not only creates the online experience, but also enhances the regular in-class environment. This method of instruction provides the opportunity for students to pursue their engineering education with the flexibility that is essential in today's business world.

The Biochemical (biopharmaceutical) Engineering graduate courses at VU

Villanova currently offers four graduate courses that comprise a "graduate certificate" in biochemical engineering. For each of these courses there is an option to take them via DE. One course covers biological and engineering challenges associated with drug delivery. A second course explores technical options and approaches fro designing and building biopharmaceutical manufacturing sites. The remaining two courses, CHE8588 and CHE8589, focus on theoretical and practical aspects of upstream and downstream bioprocessing – especially as it relates to the production of biopharmaceuticals. These courses are traditionally taken by full time and part-time graduate students in the chemical engineering department at Villanova, but on occasion by engineering students not pursuing a degree or by graduate students at Villanova and elsewhere pursuing a degree in the sciences (i.e. biology). Many of the part-time students in the classes are are currently working in some of the large pharmaceutical companies such as Merck and Company, Glaxo-SmithKline and Centocor that have large research and manufacturing sites in the greater Philadelphia area. CHE 8588 and CHE8589 cover the basics of biochemistry, immunology, cell biology and genetic engineering as well as engineering fundamentals such as mass transfer, reaction kinetics and equipment design and operation as they apply to biological systems and processes. The students are graded in these courses based upon their performance on homeworks (weekly), exams (three per course) and projects (that require reports and oral presentation). Although most examples pertain to biopharmaceutical processes, there is some emphasis on other bioprocesses including biofuels.

The MSc programme at IT Sligo (Ireland)

The pharmaceutical science programme has been jointly developed in 2007 by the School of Pharmacy at the Royal College of Surgeons in Ireland and the School of Science at the Institute of Technology, Sligo. The degree is an MSc of the National University of Ireland (NUI). It is of

interest to those working in the pharmaceutical or healthcare industries and who would like to gain an education in the main subjects related to industrial practice. The course comprises 12 modules, providing teaching in 22 major subject areas. There is also a research project. Suitable candidates include those with undergraduate degrees in engineering or basic science. The course is delivered by distance learning, with certain block attendance. The programme is organized around a two-year cycle, during which 12 modules are studied and a research project will be carried out. Each year is split into two semesters and three modules are delivered in parallel during each semester. Some of the individual modules include: Active Pharmaceutical Ingredients, Pharmaceutical microbiology, Medicinal chemistry, Pharmaceutical law, Formulation, Pharmacology and Operations management. Despite being relatively new, this programme is attracting some of the brightest scientists and engineers from across Ireland, many of whom are currently are will soon be working in the pharmaceutical industry in Ireland.

Benefits of the partnership between VU and Sligo

A significant amount of Pharmaceutical manufacturing and related jobs have moved abroad in the last 5-10 years for a variety of reasons including tax incentives, accessible ports and a well-educated workforce. This is certainly true in Ireland, where in the Cork region especially, Centocor and Wyeth for example have established research and manufacturing sites. The Sligo MSc programme was developed out of this need. Within the Sligo programme however, there as an obvious absence of engineering-based module(s). The topics covered in two courses at Villanova (CHE8588 and CHE8589), delivered via DE, were deemed to adequately provide this engineering element to the Sligo curriculum.

Other benefits of merging the graduate students from Villanova and Sligo in these two Villanova courses were identified, such as:

- Cross cultural interactions – through the in-class discussion and out-of-class group projects that these classes employ, there is the potential for exchange of different approaches and perspectives on the value and availability of new bioprocess technology and biotechnology products (i.e. drugs, sensors etc..) as well as technical challenges (eg. biofuels – cellulose source..). Such interaction is ofcourse unique and allows for development of some "softer skills" such as global communication and teamwork, an ability to work effectively in diverse and multicultural environments and an ability to synthesize engineering, business and societal perspectives in a creative, productive and ethical manner that have been identified as important and consistent with the "engineer 2020" concept[5] by a number of researchers[6].

- The addition of qualified (Sligo) students, with a diverse background and unique and global perspectives, into the Villanova classroom.

- Potential for future collaboration in different areas – this relationship establishes a foundation that may lead to other collaborations that might include: research for Villanova faculty and students on Irish issues and sites, student faculty exchange and Villanova students taking Sligo science courses via DE.

The current collaboration between Villanova and Sligo

The MOU and the program "pilot"

Villanova University and IT Sligo signed a Memorandum of Understanding in the Spring of 2010 that describes the current collaboration. The document specifies the maximum number of slots available to the Irish students – 25% of the classroom capacity (7 out of 28). The selection of students is up to the discretion of the Villanova instructor (Dr. Willam Kelly), with advisement from coordinators of graduate admission at Villanova (Dr. Vito Punzi) and at IT Sligo. Admission of the students is for only two courses: CHE 8588 and CHE8589. The Sligo students have full Villanova student privledges while taking these courses, and receive a discounted tuition in accordance with tuition standards in Ireland. As such, the students are responsible for acting in accordance with Villanova's high academic integrity as well with regards to work on exams, homeworks and projects. The possibility of some of the Sligo students continuing on at Villanova for a graduate certificate or graduate degree certainly exists, but would be contingent upon the student reapplying to Villanova directly for one of those programs. Part of the student's admission evaluation would be based on their performance in these two classes, especially if the student had a science background (BS) as compared to an engineering background (BS). The Piloting of the partnership occurred in the 2008/09 academic year, where five students successfully completed the upstream processing course (CHE8588) and four of those students completed with B+ or higher grade both CHE8588 and CHE8589. These four students had some undergraduate engineering experience, whereas the fifth student did not.The CHE8588 course is currently running in the Fall of 2010 semester with 18 in-class students, 6 US De students and 6 DE students from Sligo Ireland.

The Logistics challenges

Villanova's two graduate courses in biochemical engineering are offered every other academic year in a consecutive fall-spring format. This limits the availability of the courses not only for Villanova engineering students, but also for the Sligo MSc students, a new group of whom begins every fall semester. This schedule does however seem workable for all students incolved, provided they do the proper planning.

The lectures for graduate engineering courses at Villanova are given live once per week at 6:15 pm. This of course is quite late (11:15 pm) for the Irish students, making it difficult for some of the Irish students to watch the broadcast live and b able to participate with in-class discussions. While this can minimize the potential for cross-cultural interaction during the classroom, it does not prevent the Irish students from watching the lectures in a timely manner (perhaps during lunch the next day), since the lectures are all recorded. Exams and homeworks are delivered and received via email. The Irish students are allowed to collectively determine a convenient time during daytime hours in which they take the exam and then scan and email it back for grading. The homeworks are graded electronically with the instructor's tablet personal computer, and later returned to the students

Sligo Student Selection Challenges

The Sligo MsC is in pharmaceutical science (not engineering), consequently there students are mainly scientists UG and engineers to a lesser extent. Consequently, there is a concern that the scientists do not have the background in higher level mathematics that is sufficient to solve problems in graduate engineering courses such as CHE8588 and 8589. Currently, there are six Sligo students enrolled in CHE8588 for the fall of 2010. This list includes two mechanical/facilities type engineers and one student with an undergradaduate science (biology or chemistry) degrees but with limited math background and skills and no engineering background except for what they encountered at work (in a pharmaceutical company). Several other Irish students were interested in signing up for the course, but were advised against this before the semester began, given their lack of mathematics and engineering academic background.

Another challenge to admitting foreign students into a DE classroom offered by a US university I to assure that US export laws are followed. These laws[7] prohibit admission of students with citizenship in: Cuba, Iran and the Sudan. Consequently each of the Irish students applying for admission to the Villanova courses had to email to Villanova Council a copy of their passport for confirmation of their Irish citizenship. This prohibition does not apply to the distance instruction of students from Cuba, Sudan and Iran who are physically located in the United States at the time the distance learning services are provided.

Achieving a reasonable level of workload and mathematical rigor

With biochemical engineering courses attracting scientists (i.e. from Sligo) as well as engineers, an balance between biology and engineering topics is sought by the instructor in the classroom. There is also an attempt to present some engineering problems in lecture and for homework that require understanding of advanced math topics including solution of ordinary and partial differential equations. Since Sligo's MSc degree is NOT an engineering degree and since Ireland follows the "English" system of student evaluation which puts most of the emphasis on a single exam at the end of the semester and has few if any assignments during the semester that are collected and graded, some of the homework assignments in CHE8588 and CHE8589 are slightly less rigorous for the Sligo students. An example of one homework assignment is presented below, where the Sligo students are required to develop (but not solve) from a mass balance a differential equation for solving the steady state concentration of a reacting substrate in a porous particle that has enzymes bound to the particle surface:

HOMEWORK # 3

Due: Thursday 9/16/10 * Sligo students not required to do these parts

Your Biotech Company is interested in manufacturing catalyst particles to be used (suspended) in a stirred tank reactor. The manufacturing process will generate porous, cylindrically shaped particles (i.e. with a characteristic height - h, and radius-R) - which will allow for diffusion only through the end caps (i.e. axial, NOT radial diffusion). A local pharmaceutical company requests that you immobilize an enzyme that they use in the production of an antibiotic onto the internal surface (i.e. within the pores) of the cylindrical catalyst particles. When these catalyst particles are created, it is determined that standard Michaelis Menton kinetics are observed, where:

$V\ (mol/m^2\ s) = V_m"[S] / K_m + [S]$

With $V_m" = 1\ mol/m^2$ min, defined per unit of catalyst surface area

and $K_m = 10$ mol/l.

The catalyst particle having a density of 1.5 g/ml and 150 m^2 of internal surface area per gram of catalyst particle. The concentration of substrate in the antibiotic production process is 0.25 mol/l. The effective diffusivity of the substrate in the interior of the catalysts is 1×10^{-9} m^2/s. There is no enzyme bound to the exterior of the particle. The radius of the particles is 8μm. The conditions in the stirred tank are such that the bulk substrate concentration is equal to the substrate concentration at the entrance to the pores (i.e. no external mass transfer resistance), and is constant over time (i.e. CSTR).

a.) Develop a differential equation that represents the conservation of substrate inside the catalyst particle. List the boundary conditions.

b.) Make this differential equation dimensionless, and identify the Thiele modulus (and the parameters, such as De, that make it up).

c.) *Solve the dimensionless differential equation, obtaining the concentration profile of substrate versus position inside the catalyst particle. Apply the boundary conditions to obtain the specific solution.

d.) *Determine the relationship between the effectiveness factor and the Thiele modulus for this cylindrical catalyst particle, and plot this relationship.

e.) *Recommend the maximum particle length to use for the antibiotic production process, that ensures the reaction is not significantly (i.e. < 5% reduction from maximum possible reaction rate) reduced by internal diffusional limitations.

Ensuring interaction between the US and Irish students

The students all have the opportunity to interact through classroom discussions, which can start with questions from the DE or in-classroom students. There are also several non-technical questions posted by the instructor on the discussion board which is part of the classroom website, to promote less formal interaction between the students. Participation in these discussions is required to achieve the highest marks for the "classroom participation" portion of the grade (7% of the total grade).

The best opportunity for interaction between the DE (i.e. Sligo) students and the in-class (US) students is through mandatory group projects in which the Irish students are purposely integrated into group with the US students. One such group assignment is found below, in which all of the students were broken up into groups of three. Each group was given a specific cellulose source, ranging from switchgrass to corn stover to "Irish" grass, and was then asked to answer the following questions:

a.) Identify clearly (preferably via color pictures and diagrams) the macroscopic and molecular structure of the grass. Find general pictures (perhaps from Biology texts and internet links), that are well labeled. Label/identify and show the chemical structure of the primary cell wall macro-molecular components (i.e. lignin, pectin, xylan, hemi-cellulose, cellobiose, etc…). From researching your specific grass, indicate the percentage of the various macromolecules in the cell wall and note any unique features regarding the structure of the cell wall.

b.) Identify specific enzymes (i.e. beta-glucosidase etc..) that would be used to break down all of the grass cell wall macromolecules (identified in part a) into glucose. Be specific in describing the bonds that are broken by the specific enzymes. Indicate if these enzymes could be purchased (i.e from Novozymes Inc. etc…). Note optimal conditions (pH, temp etc…) if available for activity of these enzymes.

c.) Identify at least one microorganism that makes each of the enzymes identified in part b. Indicate where these organisms can be purchased (i.e. from ATCC etc..). Note optimal conditions (pH, temp, media components etc..) for growth of these organisms.

d.) As a group and based on what you have read in the literature, present some ideas, in the form of a few paragraphs and maybe a table or figure or so, as to how you might grow the organisms to produce the enzymes needed to degrade the specific grass that you were assigned.

Through this assignment, the students will be able to look at different aspects (i.e. options for source of cellulose, enzymes and cells as well as vendors and manufacturing approaches and technologies. In functioning on a global team, this experience prepares the students for the types of experiences that they are likely to encounter in the current workplace, and get the students approaching engineering problems with more of a global awareness.

Bibliography

1. Vest, Charles M. "Context and Challenge for Twenty-First Century Engineering Education." *Journal of Engineering Education* July 2008: 235-236

2. Borrego, Maura and Hall, T Simin. "Diffusion of Engineering Education Innovations." *Journal of Engineering Education* July 2010: 185 – 207.

3. McCormick, Kate. "Global Regulatory Framework Overview: US FDA, EMEA, PIC/S and ICH." *Pharmaceutical Engineering* May/Jun 2009: 40-48

4. Benson, Roger S. "Offshoring Life Science Production is not the Only Answer." *Pharmaceutical Engineering* July/Aug 2007: 1-6

5. National Academy of Engineering. *Educating the Engineer of 2020*. Washington DC: The National Academy Press, 2005

6. Reddish, Edward, F and Smith, Karl A. "Looking Beyond Content: Skill Development for Engineers." *Journal of Engineering Education* July 2008: 295-307.

7. www.ustreas.gov/ofac