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Innovative Integrated Curriculum in Engineering Biotechnology*

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Unique and innovative curriculum in engineering biotechnology has been created at School of Engineering Practice and Technology, Faculty of Engineering, McMaster University. The curriculum was created to address industry requirements for Bachelor of Technology (B.Tech.) with outcomes dealing with experiential learning and hands-on new technologies in Applied Bioscience, Engineering and Management. The curriculum is formed with 48% Applied Biosciences, 26% Engineering and 26% Management courses, in addition to one-year mandatory co-op on two terms of four and eight months. The curriculum is supported by state-of-the-art labs and two research centers of excellence at McMaster University. The curriculum aims to prepare students for a career in specific biotechnology industries such as: Agriculture, Food, Pharmaceutical, Forensics, Medical, Biofuel, and Regulatory Biotechnology. The curriculum reflects the unique model of Bachelor of Technology/ Biotechnology stream with Engineering, Management, and Technical (Biotechnology) components. Through this interdisciplinary curriculum, hands-on learning and innovative teaching practice, B.Tech. students are inspired to be the best in their field – both in school and at work.

Keywords: curriculum; engineering biotechnology; Bachelor of Technology

1. Introduction

Biotechnology is an interdisciplinary field. Vast developments in bioscience, biotechnology, and Bioengineering require integration of Bioscience, Engineering and Management (1–3) in interdisplinary field. This paper will discuss integrated curriculum in the Bachelor of Technology (B.Tech.) program at School of Engineering Practice and Technology (SEPT), McMaster University. B.Tech. program was designed to prepare graduates for careers in hands-on technology applications, e.g., production, manufacturing, construction supervision, project management. Students in the B.Tech programs will be technologically oriented, with a sound foundation in engineering technology complemented by management skills developed in a co-op environment. B.Tech graduates will provide highly skilled technological and management leadership within organizations developing products, services and systems.

In line with this mandate, B.Tech. program is an example of a college/university relationship which enables both institutions to make direct contributions to the economic progress of the community by providing industry-specific education that is in high demand by Ontario's employers.

The Biotechnology stream was developed by a focus group consisting of academics from McMaster University and Mohawk College. To ensure that the curriculum covers the current state of the biotechnology discipline, an Advisory Committee comprised of managers from companies related to the biotechnology industry was created. One of the distinguishing characteristics of the program is the focus on biotechnology at an industrial scale.

The curriculum aims to prepare students for a career in specific biotechnology industries such as: Agriculture, Food, Pharmaceutical, Forensics, Medical, Biofuel, and Regulatory Biotechnology. To ensure that our curriculum is industry focused, the lab and practical part of biotechnology stream curriculum covering different biotechnology industries with a program advising committee made up of prominent professionals from these various bioindustry sectors. The novelty of this curriculum is reflected on the multidisciplinary nature, the integration of co-op education, the development of interactive teaching environment, and industry-oriented course design.

2. Methodology – Means of Assessment for Biotechnology Courses

The Engineering Technology (ENG TECH) courses are designed to teach students foundational science and engineering concepts. BIO TECH courses then build on the skill and concepts taught in ENG TECH courses and, in addition, participate in hands-on experimentation. The General Technology (GEN TECH) courses are designed to complement technical skills (ENG TECH and BIO TECH), which are the clear focus of the program, with the addition of communication skills, foundational

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understanding of business management, and an ability to view the role that technology plays in a broader societal context. Through small class sizes and active learning principles and methodology, we believe that BIOTECH students are positioned to make the most of the curriculum. However, recent reviews have identified clear areas for improvement.

Recently, three BIO TECH courses were analyzed to assess how effectively the course and program learning outcomes were designed. One second year course (Biotechnology Concepts), one third year course (Industrial Biotechnology) and one fourth year course (Biopharmaceuticals) were reviewed.

- BIO TECH 2B03: Biotechnology Concepts.
- BIO TECH 3B03: Industrial Biotechnology.
- BIO TECH 4BM3: Biopharmaceuticals.

The evaluation instruments under review varied for each course, but mainly utilized final exams with a variety of exam formats (i.e. short answer questions, multiple choice, true and false, diagrams, and case study questions), in addition to mid-terms, quizzes, case studies, and assignments within the course.

Descriptive statistics were calculated to quantify areas where students did well and where they could improve. Course learning outcomes were included to demonstrate the relationship between the evaluation instrument (final exam, project or in-class active learning activities) and the course outlines' articulated purpose. The Program Learning Outcomes being addressed are also shown for each course.

Specific observations and conclusions have been documented for each of the courses assessed. In general, they reflect that the program learning outcomes are being achieved to a large extent; however, there are clearly opportunities for improvement in each of the courses analyzed.

3. Results & Discussion

In the past, it has been indicated that there is a need for courses that are professionally designed and evaluated, which adopt effective learning strategies and encourage a self-directed learning. When it comes to the area of curriculum design, an effective learning environment becomes more critical in order to improve the engagement and deliver hands-on education. We address these issues by teaching with the use of interactive multimedia learning environment. In this paper we described the usage of multimedia system from the student's perspective and we seek to understand its effectiveness in facilitating traditional lab teaching with the use of lectures, tutorials and practical sessions.

3.1 Creativity and Innovation in Biotechnology Course Curriculum

Training in Computer Programming and Software: Biotechnology students have uniquely intensive training in computer programming and different software (ENG TECH). In addition to the first year C++ programming course with a lab component, Biotechnology stream students have Computational Modeling of Biological Systems in the third year and a bioinformatics course with a lab in the fourth year where student are exposed to other programming languages such as Java, Perl, Bioperl and Python become familiar with the use of tool box to access biological databases. Biotechnology students also use computer software in Engineering Statistics, many of the GEN TECH courses, and while using instruments in their Biotechnology labs.

3.2 Mandatory 12 Month Paid Co-op Work Experience

As a requirement for graduation, all students must complete a minimum of 12 months of paid co-op work experience in a biotechnology or business field. Students have obtained work terms with companies including: Agriculture & Agri-foods Canada, Environment Canada, Apotex Inc., Sanofi Pasteur, Juravinski Cancer Centre, and Lukang American Pharmaceuticals. Most work salaries range from \$18–\$22 per hour.

3.3 Advanced Diploma from Mohawk College

Biotechnology graduates receive an Advanced Diploma in Biotechnology from Mohawk College in addition to a Bachelor of Technology degree from McMaster University. This unique integrated post-secondary model gives B.Tech graduates flexibility in the work force.

3.4 State of the Art Lab Facilities

We have dedicated biotechnology and chemical engineering labs with state-of-the-art equipment

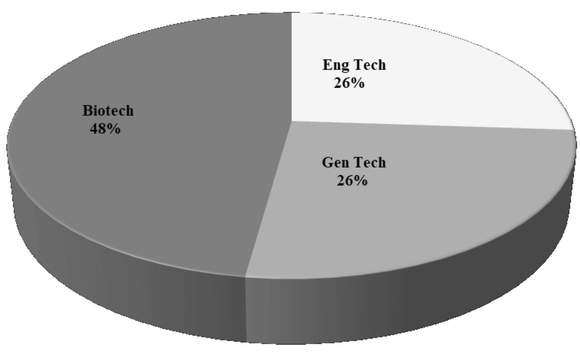

Fig. 1. Interdisciplinary components of biotechnology program curriculum.

Fig. 2. The layout of Multimedia Teaching Laboratory. The computer monitors have been installed on the top of lab bench, which achieves the real-time demonstration of microscopy images and equipment operation.

including a Biochemical Analyser, Bioreactor, Biosafety Cabinet, Fluorescent Microscope, Gel Documentation System, PCR, and HPLC system. Lab work is a central focus in our program and includes two upper year research courses where students are expected to conduct advanced research on topics at the leading edge of technology such as: biosynthesis of silver and gold nanoparticles, biosensors, second generation of biofuel, production of biodiesel using immobilized lipase, and the search for novel antibiotics. In addition to labs at McMaster, the Biotechnology stream students use Mohawk College labs particularly for courses such as Molecular Biology, Biotechnology, Microbiology, and Bioreactor Processes and Design. This unique collaborative model with Mohawk College makes efficient use of resources and avoids duplication of instruments and equipment for both institutions. The following McMaster University facilities are also used particularly for fourth year courses and the Technical Report ("capstone" project) courses.

3.5 *Use of Multimedia in Biotechnology Lab Teaching*

The introduction of an audio/visual system within the Biotechnology Lab allows for a non-traditional, multi-media enhanced teaching method (Fig. 2). Lab protocols are explained step-by-step and in real time during labs and are visible to students on monitors above their workstations (4). This helps students to work independently and allows the instructor more time for interaction with the students. The use of images and demonstrations are important in Biotechnology lab teaching because it improves safety and allows students to learn new and more complex protocols and skills. Another advantage of this method is efficient use of single and expensive lab instruments such as the Bioreactor, the Biochemical Analyzer and the Fluorescent Microscope. By transferring images and results from different lab workstations to a monitor, students can share and compare results from each workstation which aids in understanding techniques, strengthening lab discussions, and improving the writing of final lab reports. This multi-media method also allows for the transition from paper-based manuals to E-manuals.

3.6 *Industry-Oriented Teaching*

The curriculum covers most of bioindustry sectors (Fig. 3) in the form of lectures, labs. More than 30% of final year courses are taught by instructors with extensive industry experience. In addition, guest speakers from industry are invited throughout the

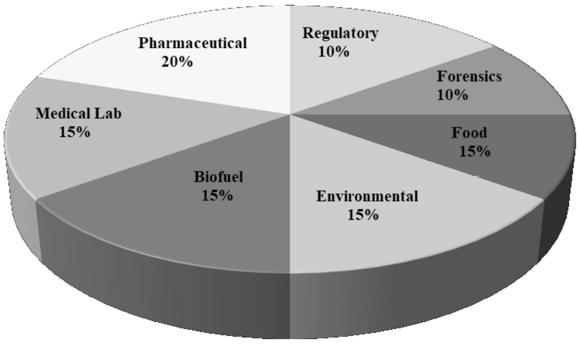

Fig. 3. Biotechnology curriculum by bioindustry sector.

Table 1. The assessment of course learning outcome in BIOTECH 2B03 Biotechnology Concepts

Course Learning Outcome	**PLO**	**0–49**	**50–59**	**60–79**	**80-100**
1. Apply the molecular biology and biotechnology concepts to genome management in industry, environment, forensics, medicine, and diagnosis.	2,4,9	2	4	15	3
2. Explain the concept of sustainable energy and its application for the biofuel and in biorefinery especially in bioethanol and biodiesel.	1,5	3	3	16	2
3. Demonstrate enzymes concepts and kinetics in free and immobilized form in food, pharmaceutical, leather, pulp/paper and detergent industries.	3,4	5	3	14	2
4. Identify the different types of stem cells and their clinical application	2,9	6	7	10	1
5. Compare biological, chemical and physical methods for the biosynthesis of nanoparticles and their applications.	3,8	5	5	10	4
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5. Compare biological, chemical and physical methods for the biosynthesis of nanoparticles and their applications.	3,8	5	5	10	4

year to speak to students in special lectures and panel discussions.

The Program Advisory Committee with representatives from various sectors within the biotechnology industry helps our program by (1) assessing programs of studies and participating in program reviews; (2) identifying skills and characteristics required of graduates and advising on equipment, laboratories and workshops; validating the learning outcomes of courses; (3) forecasting industry demand for graduates; (4) participating, when appropriate, in the development of equipment and educational partnerships; (5) advising on the identification of student co-op placement sites; (6) advising on new programming opportunities.

3.7 Mapping BIO TECH Curriculum with B. Tech Program Learning Outcomes (PLO)

Review of Biotechnology curriculum mapping (Table 1) reveals the following content:

First of all, PLOs are captured across a broad range of BIO TECH, ENG TECH and GEN TECH courses and in some cases, multiple times (6).

Secondly, the more technically oriented program learning outcomes (1–5) map well to BIO TECH and ENG TECH courses.

Thirdly, the more management-oriented program learning outcomes (6–8) map well to GEN TECH (Management) and some BIO TECH courses.

Fourthly, as a general observation, a comparison of the Biotechnology curriculum courses relative to McMaster University Degree Level Expectations indicates that the roster of courses contributes to the preparation of a well-rounded, capable graduate.

Fifthly, Level 1 and 2 BIO TECH courses contributed well to the basic technical requirements (such as program outcome: Engineering Knowledge, and Problem Analysis/Solving). However, level 3 and 4 technical courses contributed more toward applied and technical skills (such as Investigation, Design and Engineering Tools).

Sixthly, BIO TECH courses adequately addressed the technical skills requirements through lab activity and experiential learning and consequently covered effective contribution and professionalism.

The last but not the least, Technical Report I and II courses addressed many PLOs which are not addressed by other technical courses.

3.8 Course outcome Assessment

Table 1 shows BIOTECH 2B03 (Biotechnology Concepts) course assessment. Course outcome assessment reveals following conclusions: 15% of students failed to address course learning outcome (1), 10% of students failed to address course learning outcome (2), 20% of students failed to address course learning outcome (3), 30% of students

Table 2. The assessment of course learning outcome in BIOTECH 3B03 Industrial Biotechnology

Course Learning Outcome	PLO	0–49	50–59	60–79	80–100
1. Evaluate different types of mutation and their role in human genetic diseases	2,3	5	3	19	5
2. Distinguish between recombinant DNA technology in different systems such as microbial, animal, and plant systems	1,3	3	5	18	6
3. Apply biotechnology concepts and methods in medicine and industry	1,4,9	6	6	16	4
4. Recognize protein as a biotechnology product and its production, purification and scale-up	4,5	9	6	15	2
5. Perform safely the different recombinant DNA technology and biotechnology techniques in laboratory.	5,8,9	3	3	18	8

Table 3. The assessment of course learning outcome in BIO TECH 4BM3 – Biopharmaceuticals

Course Learning Outcome	PLO	0–49	50–59	60–79	80–100
1. Describe and explain the process of biopharmaceutical drug development and manufacture.	5,9	1	5	18	5
2. Use critical thinking to determine possible applications of various types of macromolecules.	3,4	2	6	15	6
3. Explain the role of each class of macromolecule found in the body as well as how they can be transformed into biopharmaceuticals	1,2	2	4	18	5
4. Understand the purpose and details of good manufacturing practice	5,8,9	1	4	17	6

failed to address course learning outcome (4), and 10% of students failed to address course learning outcome (5).

Table 2 depict BIO TECH 3BO3 (Industrial Biotechnology) course assessment. Course outcome assessment reveals following conclusions: 10% of students failed to address course learning outcome (1), 15% of students failed to address course learning outcome (2), 20% of students failed to address course learning outcome (3), 25% of students failed to address course learning outcome (4), 20% of students failed to address course learning outcome (5).

Table 3 depict BIO TECH 4BMO3 (Biopharmaceuticals) Course outcome assessment reveals following conclusions: 5% of students failed to address course learning outcome (1), 10% of students failed to address course learning outcome (2), 10% of students failed to address course learning outcome (3), 5% of students failed to address course learning outcome (4). Mapping of Biotechnology curriculum with PLO has been shown in the appendix.

4. Conclusions

In this paper, we have demonstrated that the innovative integrated curriculum in engineering biotechnology provides multidisciplinary and industry-oriented education, interactive learning environment, and co-op experience. This innovative curriculum design allows us to achieve the program learning outcome and to better enhance the experiential learning.

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Appendix

Mapping of Biotechnology curriculum with PLO

Course Code	Course Names	1. Engineering Knowledge	2. Problem Analysis/Solving	3. Investigation	4. Design	5. Engineering Tools	6. Business Management	7. Communications	8. Effective Contribution	9. Professionalism
Level 1A										
ENG TECH 1CH3	Chemistry	3	3	1	0	1	1	1	0	0
ENG TECH1CP3	C++ Programming	3	3	0	1	2	0	0	0	0
ENG TECH 1MC3	Mathematics 1	3	3	0	0	0	0	1	0	0
ENG TECH 1PH3	Physics	3	3	2	0	1	0	0	0	0
GEN TECH 1CS3	Technical Communication: Concepts and Practices	0	0	0	0	0	1	3	3	2
Level 1B										
ENG TECH 1AC3	Analytical Chemistry	3	3	2	0	1	0	1	0	0
ENG TECH 1BI3	Biology	3	2	1	0	1	0	0	0	0
ENG TECH 1EL3	Electricity & Electronics 1	3	3	3	0	2	0	1	1	0
ENG TECH 1MT3	Mathematics 2	3	3	0	0	0	0	0	0	0
GEN TECH 1CZ3	Technical Communication: Research and information Design	0	2	3	0	0	2	3	3	3
Level IIA										
BIOTECH 2CB3	Cell Biology	3	2	2	1	2	1	1	0	1
BIOTECH 2EC3	Chemical Engineering Concepts	2	3	2	2	3	0	0	1	1
BIOTECH 2M03	Molecular Biology	3	1	2	1	2	0	1	1	1
BIOTECH 2OC3	Organic Chemistry	3	2	2	0	2	1	1	1	1
ENG TECH 2MA3	Mathematics 3	3	3	0	0	0	0	0	0	0
GEN TECH 2PW3	Professional Workplace Practices	0	0	2	0	0	3	3	3	3
Level IIB										
BIOTECH 2BC3	Biochemistry	3	1	2	1	2	0	1	1	2
BIOTECH 2B03	Biotechnology Concepts	3	2	2	2	2	1	1	2	2
BIOTECH 2GT3	Genetics	3	2	3	1	2	1	1	2	2
BIOTECH 2MB3	Microbiology	2	2	3	1	2	0	1	2	1
GEN TECH 2EE3	Engineering Economics	1	3	0	2	3	3	2	1	2
GEN TECH 2MP3	Management Principles	0	2	1	1	0	3	3	3	3
Level IIIA										
BIOTECH 3B03	Industrial Biotechnology	2	2	3	2	3	1	1	1	2
BIOTECH 3IV3	Immunology & Virology	2	2	3	1	3	1	2	2	2
ENG TECH 3ES3	Engineering Statistics	1	3	1	1	2	1	3	1	1
GEN TECH 3MT3	Project Management	1	2	2	2	2	3	3	3	2
GEN TECH 3FF3	Financial Systems	0	2	3	2	0	2	3	3	3

Course Code	Course Names	1. Engineering Knowledge	2. Problem Analysis/Solving	3. Investigation	4. Design	5. Engineering Tools	6. Business Management	7. Communications	8. Effective Contribution	9. Professionalism
Level IIIB										
BIOTECH 3BP3	Bioreactor Processes & Design	2	3	1	2	3	0	2	1	2
BIOTECH 3FM3	Food Microbiology	2	2	1	1	2	1	1	2	2
BIOTECH 3CM3	Computational Modeling of Biological Systems	3	2	2	2	2	0	2	2	2
BIOTECH 3PM3	Pharmacology	2	2	3	2	3	0	1	1	2
GEN TECH 3LS3	Quality Control and Assurance Methods	0	2	2	2	0	3	3	3	3
GEN TECH 3ET3	Entrepreneurial Thinking and Innovation	1	2	2	2	2	3	3	3	2
Level IVA										
BIO TECH 4BL3	Biomaterials and Biocompatibility	2	2	3	2	3	1	0	1	2
BIO TECH 4BM3	Biopharmaceuticals	2	2	2	1	3	1	1	2	2
BIOTECH 4GP3	Genomics & Proteomics	2	2	3	1	3	1	2	2	2
BIOTECH 4TR1	Capstone Project I	1	3	3	2	3	2	3	2	3
GEN TECH 4TS3	Technology & Society	0	2	3	0	0	2	3	3	3
GEN TECH 4OM3	Operation Management	3	3	3	2	3	3	2	2	1
Level IVB										
BIOTECH 4BI3	Bioinformatics	1	3	3	2	3	1	2	2	2
BIOTECH 4BS3	Biotechnology Regulations	0	2	3	2	3	2	1	2	2
BIOTECH 4TB3	Advanced Biotechnology	1	2	3	2	3	1	1	2	2
BIOTECH 4TR3	Capstone Project II	2	3	3	3	3	2	3	2	3
GEN TECH 4FT3	Strategic Management	1	2	2	1	2	3	2	3	3
GEN TECH 4TE3	Technology Ethics and Sustainability	0	2	2	1	0	3	3	3	3

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