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# Integrating Interdisciplinary Research-based Experiences in Biotechnology Laboratories

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## ABSTRACT

The increasingly interdisciplinary nature of today's scientific research is leading to the transformation of undergraduate education. In addressing these needs, the University of Houston's College of Technology has developed a new interdisciplinary research–based biotechnology laboratory curriculum. Using the pesticide degrading bacterium, *Brevundimonas diminuta,* as an anchor organism, the curriculum follows a logical progression starting with isolation and identification of pesticide degrading soil microbes, gene cloning, gene expression, bioprocessing of the gene product and commercial applications, thus demonstrating the life cycle of a typical biotechnology product. These series of laboratory protocols use a guided inquiry method to teach appropriate techniques and skills and help students build a bridge between materials presented in courses and applications in real life. Students then apply these concepts and techniques in independently designed investigations. The modular nature of this curriculum makes it flexible for integration into a variety of courses and could serve as a model for interdisciplinary education.

**Keywords:** research-based experiences, interdisciplinary, biotechnology

## INTRODUCTION

Hands-on undergraduate laboratories that connect content to techniques are an integral part of science and engineering curriculum. While these laboratories demonstrate the relationship between principles and techniques, they are often limited to providing hands-on experiences with the techniques themselves. Demonstration of the relevance of these techniques and methods to research and real world applications is rare. This issue is complicated by the fact that research is becoming increasingly interdisciplinary with concepts and techniques from science, engineering and technology combining to answer fundamental and applied problems. In addressing this challenge, several reports have recommended incorporating these changes into undergraduate curricula to produce the next generation of researchers that will be prepared and suited to working in an interdisciplinary environment (1–6).

As the research environment becomes increasingly cross-disciplinary, a natural evolution of undergraduate education will include the adoption of interdisciplinary instruction in both the classroom and the laboratory. Integration of interdisciplinary elements into undergraduate education will help students appreciate the interconnectivity between disciplines, and its significance in scientific discovery and application. Many of the recent reports focused on transforming undergraduate education emphasize the importance of research experiences during undergraduate years (7–13).

Educators today are faced with the challenge of (1) providing students with the skills and knowledge required for cross-discipline success and (2) engaging students in research experiences that will motivate and retain them in STEM-related fields. Undergraduate research experiences (REU) help to address both these objectives. It has been demonstrated that REU can play a role in increased student retention, graduation rates, entrance into graduate schools and motivation to pursue advance degrees and careers in science (7–13). Providing research experiences during the undergraduate years exposes students to different facets of science not available in a regular curriculum. Over the past decade, efforts to change curricular materials to include interdisciplinary elements and inquiry-based activities have increased. Universities have taken on the challenge (14 -21), and innovative instruction has been applied to complex interdisciplinary issues that foster an understanding between disciplines (15–17) or within discipline (18–21).

To address these challenges, the University of Houston's College of Technology developed a new biotechnology research-based laboratory curriculum in conjunction with a new undergraduate biotechnology degree program. As a discipline, biotechnology interfaces biology with engineering, technology and computer science, and serves as an ideal platform to engage in interdisciplinary education. In the biotechnology industry, scientists make up a large fraction of employees (22, 23), in both early stage and large biotech firms, with careers spanning discovery, research & development (R &D) and manufacturing of the biotech product. Biotechnology work therefore requires an appreciation of the significance of scientific discovery to commercial application. This paper describes the new curriculum, beta-testing of the new curriculum and preliminary assessment and evaluation data.

## INTERDISCIPLINARY RESEARCH–BASED BIOTECHNOLOGY CURRICULUM

The objectives of the new biotechnology curriculum are to:

1. Design an interdisciplinary curriculum that will prepare the students to work in an interdisciplinary research environment. To address this challenge, the life cycle of a typical biotechnology product provides the framework within which to integrate the requisite cross-disciplinary skills. As the life cycle of a biotech product is traced from problem recognition, discovery, R&D, manufacturing and application, students experience the application of the scientific process to real world problems, and the value of everyday scientific discoveries in the world around them. Such an effort transcends disciplinary boundaries and reflects the curricular changes needed to transform undergraduate education.
2. Provide a research experience that is integrated within the curriculum itself, so that all students enrolled in the program benefit. This model is different than the traditional model, where students conduct independent summer research projects under a faculty mentor.

The laboratory curriculum is designed to demonstrate the continuum of science, guiding students through the process of scientific discovery and investigation, and follow the development and application to real world problems. A research area in which scientists across academic institutions and disciplines are currently active was selected as the framework, so that students can follow current progress in the field, while conducting their own experiments. Broadly, the topic of environmental biotechnology and bioprocessing was selected. This research discipline not only meets the programmatic needs, but is also timely and of significant public interest. In understanding the principles of environmental biotechnology and bioprocessing, students gain knowledge on how living systems manage their chemistry in comparison with equivalent industrial processes and are introduced to the concept of process sustainability, where wastes generated by biological processes are recyclable or biodegradable. The modular nature of the curriculum provides the flexibility required for integration into a variety of interdisciplinary courses. The integration of research experiences provides opportunities for future projects for undergraduates and builds a foundation for basic and applied research for the Center for Life Sciences Technology at the University of Houston.

### Project-based Learning: Environmental Biotechnology and Organophosphorous Degradation

The soil bacterium *Brevundimonas diminuta* (previously classified as *Pseudomonas diminuta)* is the model for this project-based curriculum. A plasmid-encoded gene (*opd*) is responsible for production of the enzyme organophosphorous hydrolase (OPH), which is involved in the degradation of organophosphorous (OP) compounds. OP compounds are potent cholinesterase inhibitors, accounting for their widespread use as insecticides and chemical warfare agents. This class of compound includes pesticides such as Parathion, Diazinon™, Chlorpyrifos (e.g., Dursban™), and glyphosate (e.g. Roundup™), as well as the chemical warfare agents Tabun (GA), Soman (GD), Sarin (GB), Cyclosarin and VX. In addition to the nearly 3 million cases of pesticide poisonings world-wide each year attributed to OP pesticides (24), there are risks associated with the major international effort to destroy the approximately 25,000 tons of stockpiled chemical agents (25). The use of OP insecticides increased during the 1970's and 1980's, primarily as replacements for the more persistent chlorinated pesticides. In comparison, the relative lack of persistence of the organophosphates can be attributed to their susceptibility to hydrolysis by microbial enzymes. By the late 1980's, there were reports of the reduced efficacy of these compounds in "problem" soils, where pesticide metabolism was apparently enhanced by the increasing prevalence of these hydrolytic enzymes (26). The nature of this enhanced metabolism, as well as the potential use of microbial degradative enzymes for pesticide waste detoxification has led to an interest in developing these hydrolases as potential remediation enzymes (27).

The OP system was chosen to develop the curriculum because of the ease with which it can be integrated into the undergraduate curriculum. The bacteria are commonly found in soil and are easy to detect, isolate and maintain. There are a number of genes involved in OP pesticide degradation that have been identified, cloned and characterized (28–30). The associated proteins are easily expressed and upstream and downstream processes for protein production are well characterized in the literature (31–33). The potential application of this research in biosecurity, food security and worker safety makes it valuable to undergraduate curricula, enabling students to relate the value of scientific discovery in everyday life.

### Modular Research-based Interdisciplinary Laboratory Curriculum

Laboratory activities are divided into three modules (Figure 1). Module I demonstrates the discovery process and consists of collection of environmental soil samples to isolate OP pesticide-degrading microbes. Module II contains techniques that include isolating, cloning, and transgenic expression of the pesticide-degrading gene. Module III consists of activities that emulate production of a biotech product, in our case activities that are related to growing transformed cells in a bioreactor for optimum production which is then followed by purification of the recombinant protein using traditional downstream processes.

#### *Module I: Environmental Sampling*

This module is an investigative /discovery module that provides research experiences for students as they are challenged to pose questions, develop a hypothesis and collect data to support or refute their hypothesis. A sample question might be, "is this activity seen in all soil samples?" The students then formulate a hypothesis and develop a research strategy to either validate or refute their hypothesis.

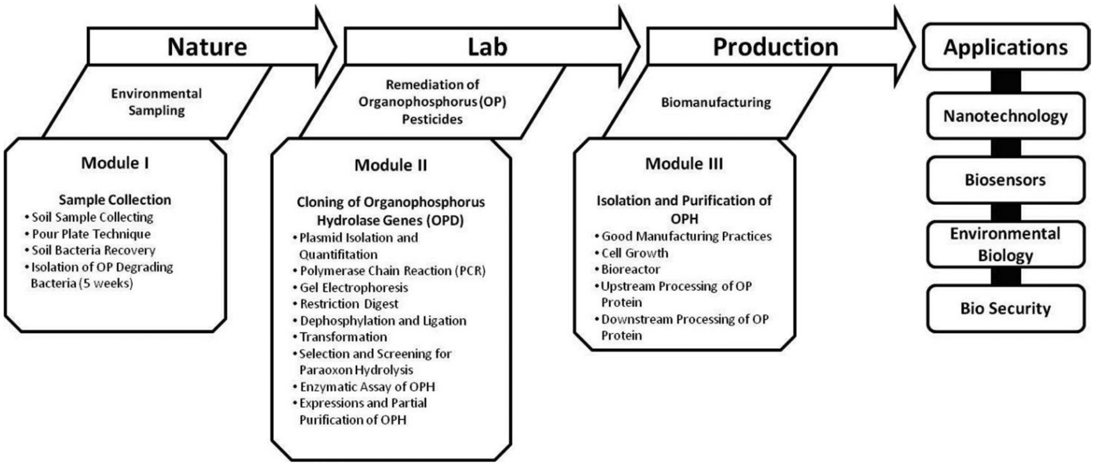


***Figure 1. Overview of Laboratory Activities.***

Although students can collect a soil sample for any location, depending on their hypothesis, locations that have agricultural fields with frequent pesticide application are obvious selections. The laboratory exercise directs students to collect approximately 10 grams of soil in a sterile tube and record the date, time and location of the sample. The sample is then processed in the laboratory following the protocol to enrich and isolate OP hydrolyzing bacteria. Briefly, the protocol enriches for OP degrading bacteria through incubation on minimal media supplemented with a model OP compound. Following four cycles of sub- culturing, the bacterial fraction is harvested and plated on OP enriched plates for screening. In addition, students also perform basic microbiological techniques such as Gram stain, streak and spread plating of cultures, nutrient requirement and antibiotic resistance.

At the end of the project, students submit a research paper on their field and laboratory activities. Students are assessed on the following criteria: (1) Introduction to the project, (2) Formulation of the hypothesis, (3) The experimental procedure, (4) Observations, (5) Analysis, results and conclusions.

***Module II: Remediation of Organophosphorous Compounds***

As in many scientific discoveries, once a microorganism is identified to have a particular function, the next step is to assign that function to a particular gene or a set of genes. Research on the biochemistry of OP compound degradation has shown the biochemistry of degradation to be limited to family of enzymes. The encoding genes have been isolated from geographically different regions and taxonomically different species. Many such genes have been sequenced, cloned and expressed in a variety of different systems (28–33).

The aim of this module is to demonstrate the research activities that are normally conducted following a discovery with a potential commercial application. This application could be environmental, health, agriculture or animal biotechnology. Module II consists of activities that include the molecular techniques of cloning the target gene, followed by analysis and screening of clones for desired activity, which in this case is pesticide degradation (Figure 1).

***Module III - Bioprocessing***

Most laboratory curriculum cover the foundational concepts of biotechnology, such as basic molecular and biochemical techniques, but do not include the current technological advances in the field. The bioprocessing module is developed to provide hands-on experience with both the upstream and downstream processes of protein production and purification. The integration of this module connects discovery, research and development to bioprocessing and manufacturing and demonstrates the continuum of a typical biotechnology process. This module provides an overview on how biotechnology products are produced in a pharmaceutical/biotech facility. The production is divided into "upstream" and "downstream" processing. Upstream refers to the initial fermentation and associated processes, which result in the generation of the cellular biomass. Downstream processing refers to biomass processing, which may include harvesting, spray or freeze drying of the harvested biomass, or purification steps for the recovery and enzymatic characterization of a protein product (Figure 1).

The upstream activities are facilitated by the use of three New Brunswick BioFlow 110 fermentors, each with a 2L capacity. Students use *Escherichia coli* strain DH5 transformed with the vector pOP419, which carries the *opd* gene and *bla* ( lactamase) gene for selection (33). Cells are grown in BioFlo growth media (New Brunswick Scientific, NJ) that consists of 7 g $KH_2PO_4$, 10 g $K_2HPO_4$, 10 g $(NH_4)_2SO_4$, 10 g Yeast Extract dissolved in 1000 mL of MilliQ water. After a period of three days, students harvest the cultures using proper aseptic techniques.

Downstream processing is the most elaborate part of the module and is divided into three sub-processing steps: initial preparation, intermediate preparation, and final preparation. In initial preparation, students study various techniques in cell lysis and batch processing of crude cell free extracts, including enzymatic and mechanical lysis, and batch precipitation steps utilizing streptomycin and/or salts such as ammonium sulfate. The resultant preparation is then advanced to intermediate preparation, where it is subjected to various chromatography steps utilizing an AKTAprime FPLC (GE Healthcare, Life Sciences, Piscataway, NJ). Students learn proper techniques in column chromatography since this technique is essential in industrial preparation of biological products. In the final preparation stage, students apply basic techniques from biochemistry and enzymology to characterize the protein product, utilizing standard assays to determine quantity and specific activity. This step provides students with feedback, allowing them to assess performance during fermentation and purification, as well as teaching them the process of quality assurance.

**Modular Flexibility: Implementation and Strategies of the Biotechnology Laboratory Curriculum**

The UH Biotechnology Program consists of a 123 credit hour degree plan; nine new courses were developed for the program (Appendix A). The program has two tracks: bio-manufacturing and bio-informatics. Two biotechnology laboratory courses in the program are BTEC 3100: Biotechnology Research Methods and Applications and BTEC 4101: Principles of Bioprocessing laboratory. BTEC 3100 is a core course and is required for all students majoring in Biotechnology. BTEC 4101 is part of the bio-manufacturing track and is required for students in this particular track.

In 2007, modules I and II were beta-tested at Brigham Young – Hawaii, a collaborating institution, as courses-in-series in the summer and fall (Figure 2). The following year, Module I and II were simultaneously beta-tested in at the University of Houston in BTEC 3100: Biotechnology Research Methods and Applications (Figure 2). Module I was beta-tested as a laboratory-based research project in which students collected soil samples from various locations in the greater Houston area and followed established protocols for isolation of pesticide-degrading bacteria. Students began Module II concurrently by amplification of the *opd* gene from prepared material followed by insertion into a plasmid. At the end of the course, Module III was discussed in recitation sections, thus providing a brief introduction for students not entering the bio-manufacturing track. In spring 2009, Module III was beta-tested in BTEC 4350: Capstone Experience. Offering the modules concurrently provided students with hands-on experience, demonstrated the interconnectivity of the techniques and benefited students from both tracks.

## PRELIMINARY DATA ON ASSESSMENT AND STUDENT EVALUATION

The long-term goal of this project is to design, develop and implement interdisciplinary teaching material and test its impact on student learning outcomes. The new curriculum therefore has both student and instructor centered goals. The following is not a complete list, but rather examples of outcomes resulting from this project. Students will be able to:

- Demonstrate their ability to reason both inductively and deductively with experimental information and data.
- Explain the theory and practice of recombinant DNA technology.
- Describe biocatalysis, bioprocess control, upstream and downstream processing.

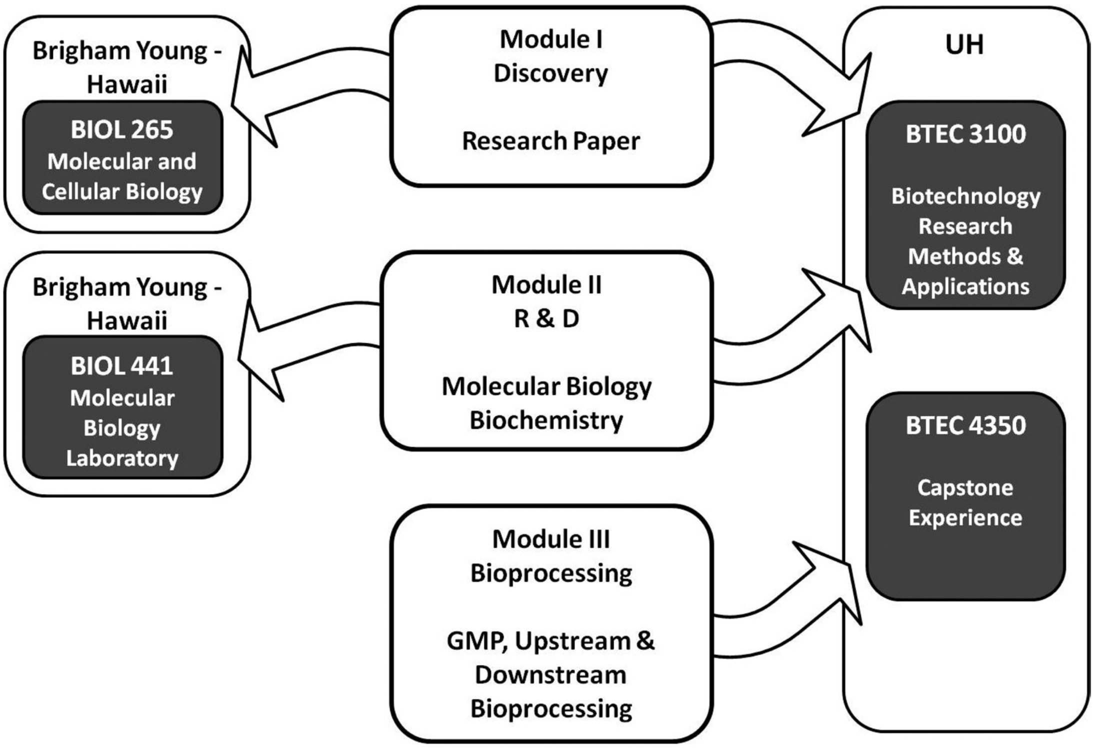


***Figure 2. Beta-testing Modules into New Biotechnology Courses.***

- Apply concepts of biology, chemistry, mathematics and engineering procedures to the spectrum of fields making use of biotechnology.
- Integrate collaborative and investigative learning to build critical thinking skills.

The project also has instructor-centered goals that include:

- Developing a project-based curriculum that integrates new technological advances into biotechnology curriculum.
- Designing and disseminating laboratory activities that can be integrated into appropriate curricula.
- Develop an instructor's manual that will guide in implementing this curriculum.

Assessment plans for student-centered objectives include formative assessments to improve and refine the model and summative assessments to judge the impact of the model. Because the learning objectives were established early in the design process, a clear link was created between the activities and student learning.

The learner-centered assessment consists of two main parts. The first phase involves testing the effectiveness of integration of modules in terms of knowledge, skills and overall impact. Student success is measured through laboratory journals, quizzes, exams, presentations and written assignments. These are used as assessments of student knowledge and skills (Table 1). Preliminary results from these assessments suggest that the students successfully learned the skills and knowledge as defined by the curriculum learning goals.

The second phase consists of a self-assessment of student learning and attitude using the Student Assessment of Learning Gains (SALG) instrument (Appendix B). The SALG is an easily individualized evaluative tool that uses a course survey to learn what aspects of the course students feel are most important to their learning and gauge their attitude to various activities (www.salsite.org). The instrument is a generalized survey tool consisting of fixed-response statements and open-ended questions. The survey asks students to self-rate how each component (e.g. course content, tests, labs) facilitated learning and gains towards achieving the course goals. In particular, students are guided to assess and report on their own learning and the degree to which specific aspects of the course contributed to that learning. The reporting of learning gains by the students may differ in the qualitative application of the graded terms since each individual student assess and report on their own learning experience ("great", "much", etc). As part of the survey, students were asked to rate the following components: (1) Class overall, (2) Class activities, (3) Class assignments, (4) Class resources, (5) Information provided, (6) Support for the students as an individual learner, (7) Understanding of class content, (8) Increase in skills, (9) Class impact on attitudes, and (10) Integration of learning.

**Preliminary Assessment for Module I and II**

Preliminary data on direct student assessment indicates that students successfully acquired skills encompassed in module I, as assessed by their performance related to collecting, processing

| Skills | Performance Measures | Module I | Module II | Module III |
|---|---|---|---|---|
| Ability to collect data | Soil sample collection, Cell Fermentation | X | | X |
| Ability to process data | Guided lab activity | X | X | X |
| Ability to analyze sample | Guided lab activity | X | X | X |
| Interpretation of data | Research paper | X | | X |
| Demonstrate the ability to communicate in a technical format | Laboratory notebook, quizzes | X | X | X |
| Demonstrate knowledge of technical concepts and skills relevant to the discipline | Laboratory note book, quizzes, tests. | X | X | X |

***Table 1: Mapping Of Skills to Performance Measures and Modules.***

and analysis of the sample and interpretation of data. Students were also able to demonstrate skills related to module II as assessed by their laboratory performance, lab book documentation and performance quizzes (Table 1). All the students demonstrated competence in the intended skills and knowledge areas as assessed by the performance measures.

Preliminary data on indirect assessment using SALG results indicate that students perceived learning gains with the interdisciplinary research-based approach used in the new biotechnology laboratory. Students were positive about the learning environment for module I and II. Aggregate responses to 42 out of 68 items indicate these activities were viewed as much help or better by students. Figure 3 summarizes student responses to the SALG questions regarding their learning gains with respect to the modules overall.

1. With respect to the instructional approach taken in the class, 57% reported great help and 43% reported much help. (Item 1.1)
2. With respect to how the class topics, activities, reading and assignments fit together, 71% reported great help and 29% reported much help. (Item 1.2)
3. With respect to the pace of the class, 71% reported great help and 29% reported much help. (Item 1.3)

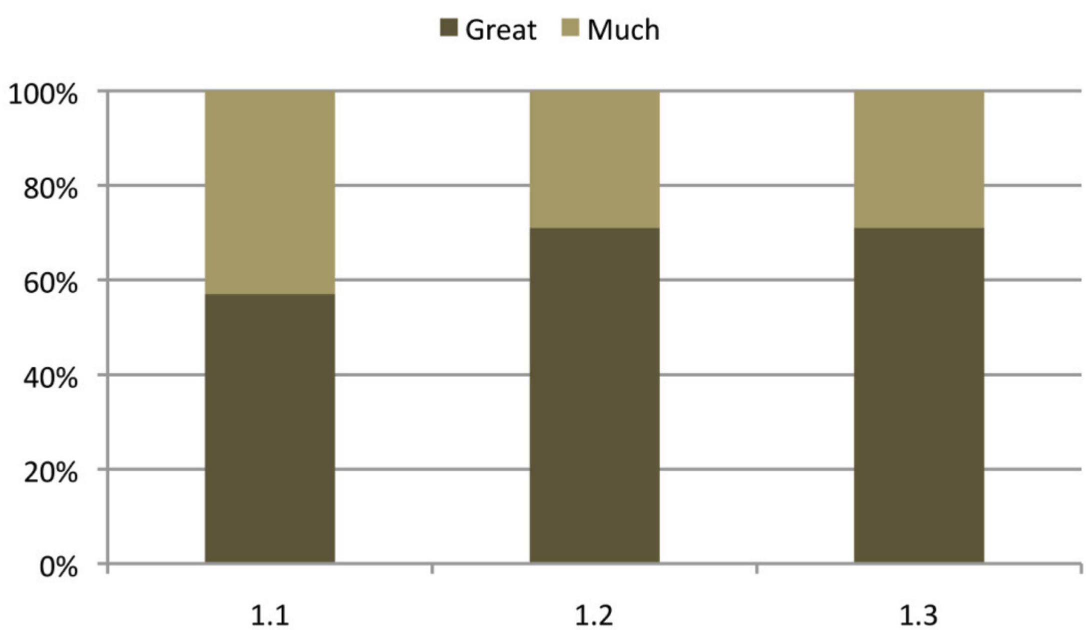


***Figure 3. Student Assessment of Learning Gains with Respect to the Class Overall.***

One student commented: “I have been able to think and observe more like a scientist since I was able to do hands-on work.” For details on SALG responses for fall 2008, please refer to Appendix C.

Data on assessment of student gains in integration of their learning are summarized in Figure 4, and below:

Connecting key ideas with other knowledge (Item 10.1), 100% reported great help.

1. Applying what the student learned in the class in other situations (Item 10.2), 86% reported great help and 14% reported much help.
2. Using systematic reasoning in the students’ approach to problems (Item 10.3), 86% reported great help and 14% reported much help.
3. Using a critical approach to analyzing data and arguments in the students daily life (Item 10.4), 71% reported great help and 29% reported much help.

Students also indicated that they will be able to translate several skills (including writing lab reports, public speaking and research skills) into other courses.

**Preliminary Assessment for Module III**

Preliminary data on direct student assessment indicates that students successfully acquired skills encompassed in Module III. Skills and knowledge were assessed for sample collecting, data processing

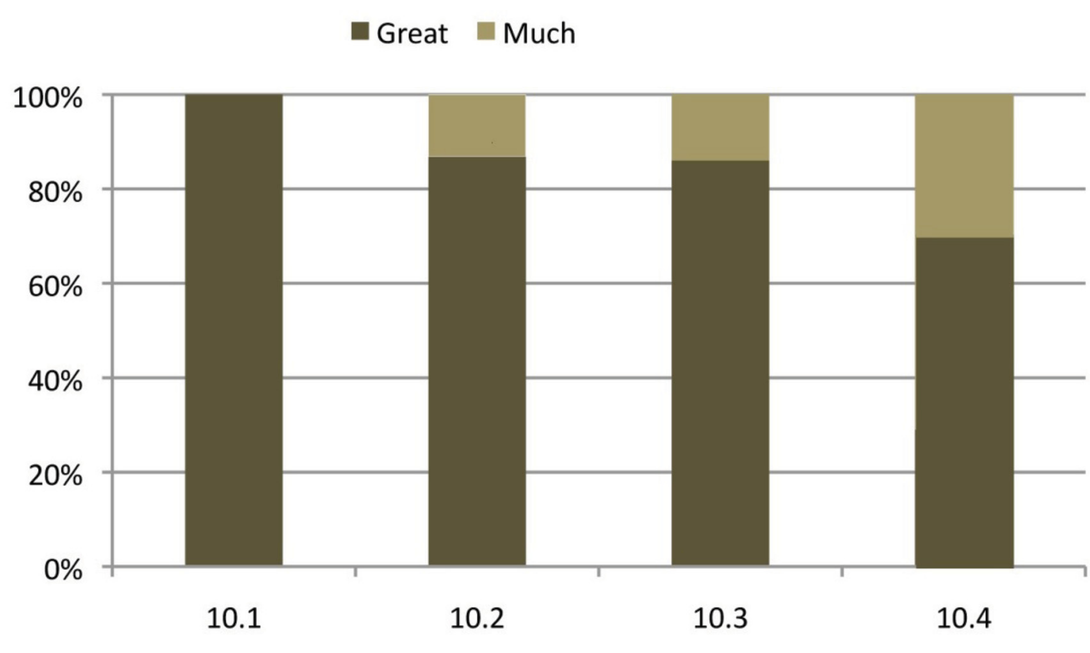


***Figure 4. Student Assessment Learning Gains in Integration of Learning.***

and analysis, writing research papers, documenting experimental details using laboratory notebooks and performance on quizzes (Table 1). Preliminary results indicate 100% of students' demonstrated competence in the intended skills and knowledge as assessed by the performance measures.

Preliminary SALG results indicate that students were positive about the learning environment for Module III (Appendix D), 100% reported that the class was of great help with respect to:

1. The instructional approach taken in the class,
2. How the class topics, activities, reading and assignments fit together, and
3. The pace of the class.

For the same module, outcomes for item 10 regarding student gains in integration of their learning were as follows:

1. Connecting key ideas with other knowledge (Item 10.1), 66% reported great help, 33% reported moderate help.
2. Applying what the student learned in the class in other situations (Item 10.2), 66% reported great help and 33% much help.
3. Using systematic reasoning in the students' approach to problems (Item 10.3), 100% reported great help.
4. Using a critical approach to analyzing data and arguments in the student's daily life (Item 10.4), 66% reported much help and 33% not applicable.

For instructor centered goals, the modules were peer reviewed by faculty at the University of Houston, members of the Center for Life Sciences Board and faculty at other universities, including Brigham Young University-Hawaii, Houston Community College and the teaching assistants who assisted during the implementation phase. Reviewer recommendations are being implemented and the project will be disseminated as a laboratory manual.

## DISCUSSION

In response to recommendations for renovation of undergraduate education, interdisciplinary research-based experiences were developed for the new biotechnology laboratory curriculum at the University of Houston (34). According to Tanner and Allen (35), the process of developing new courses at most colleges and universities is localized, with individual professors or committees deciding course content. In this case, a new biotechnology laboratory curriculum was developed in collaboration with industry and academic partners and is designed to integrate technical and interdisciplinary skills (Table 1). Members of the industry advisory committee guided the development of courses, including, Biotechnology Regulatory Environment, Current Good Manufacturing Practices and Quality Assurance Quality Control. Industry relevant issues were taken into consideration in developing these courses, which support and connect the laboratory skills instruction to the real world. The new curriculum also provides research experience that is integrated within the curriculum and is different than the traditional model, where students conduct independent research projects under a faculty mentor. To address the interdisciplinary objective, the life cycle of a typical biotechnology product is traced from problem recognition, discovery, R&D, manufacturing and application. Such an effort transcends disciplinary boundaries, and engages students in both scientific inquiry and engineering design and process development. The series of laboratory protocols use a guided-inquiry method to teach the appropriate techniques and skills, and help students bridge materials presented in courses and real-world applications. Students mature in concert with the projects, applying concepts and techniques in independently designed investigations. This learner-focused pedagogical approach integrated with active learning is consistent with research that suggests that students learn more effectively when they are active participants in their own learning rather than passive recipients of knowledge (36–38).

Ongoing review and modification of the modules will develop, refine and assess teaching strategies that encourage research-based interdisciplinary learning using a two-tiered approach: First, the Biotech program participates in a yearly evaluation of performance relative to the learning goals of the undergraduate degree program, which are: (1) Students will demonstrate biotechnology laboratory skills, (2) Students will demonstrate ability to present research results in front of an audience, (3) Students will demonstrate the ability to collect and analyze data and (4) Students will demonstrate knowledge of regulatory issues and practices in the biotechnology industry. Second, the Program Director, in collaboration with the Assistant Dean for Assessment and Accreditation for the College of Technology, continues to refine performance measures across the curriculum to ensure that skills and knowledge are being accurately assessed. For example, the BTEC 3100 research paper rubric is currently being reviewed against the learning goals to determine if changes are needed to enhance its usefulness as a measurement tool.

## CONCLUSION

This paper describes a novel interdisciplinary research–based curriculum and preliminary data from beta-testing of new curriculum in the new biotechnology laboratories at the University of Houston's College of Technology. The focus of this effort is to develop a series of courses for a new biotechnology undergraduate degree program, developing course content, program outcomes and student assessment tools to measure student learning gains as the program progresses. This approach offers a breadth of applied and student-centered learning quite different from standard approaches to biotechnology education.

The structure of the curriculum provides a logical coordination between the biotechnology modules, yet it is flexible enough to be integrated into other courses such as microbiology, genetics, and environmental sciences and bioprocessing. Preliminary data on beta-testing the new curriculum indicates that these modules can be successfully integrated into new or existing courses.

Only in its second year, the degree enrollment has increased from fewer than 10 the first year to 80 declared majors, reflecting student interest in both the topic and the curriculum. Specific outcomes of the first two years include the following:

- The modular nature of the laboratories provides an ease of adoption that supports a variety of curriculum designs and implementation strategies. The UH implemented the modules as a single independent study course in the first year, when student enrollment was small, and progressed to a teaching laboratory format by the second year to meet increased student demand and enrollment. BYU, Hawaii implemented the modules in existing laboratory courses demonstrating the flexibility of the curriculum.
- As concepts, knowledge and skills build, students assume more independence in their laboratory experiences, ending in a capstone project of their own design.
- An exciting, but not fully anticipated, aspect of the program is the ease with which the designed laboratory protocols transition from guided instruction to learner-focused accelerator projects. For example, two field samples from BTEC 3100: Biotechnology Research Methods and Applications demonstrated pesticide degradation capability, and formed the basis for continued student engagement in projects such as specificity of pesticide tolerance development and introductory microbial ecology using techniques such as colony isolate and rDNA profiling. This facilitates and sustains student engagement and enthusiasm, allowing skills and concepts to mature as the project develops.
- Collaborations with other institutions both nationally and regionally provide a Platform for Education and Research Collaboration (PERC) to connect students and faculty across cultures and geographical distribution.

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## Appendix A: Biotechnology Degree Plan

**UNIVERSITY CORE REQUIREMENTS (42 SH)**

| | GR | SH | AH |
|---|---|---|---|
| **Communication (6 SH)** | | | |
| ENGL 1303 English Composition I | ____ | ____ | ____ |
| ENGL 1304 English Composition II | ____ | ____ | ____ |
| **Writing in the Discipline (WID) (3SH)*** | | | |
| COMM 1302 (preferred) | ____ | ____ | ____ |
| **History/Government (12 SH)** | | | |
| HIST 1377 US History to 1867 | ____ | ____ | ____ |
| HIST 1379 US History since 1867 | ____ | ____ | ____ |
| POLS 1336 US & TX Const/Politics | ____ | ____ | ____ |
| POLS 1337 US Government | ____ | ____ | ____ |
| **Humanities* (3 SH)** | | | |
| Phil 1305 Ethics | ____ | ____ | ____ |
| **Visual/Performing Arts* (3 SH)** | | | |
| ______________________________ | ____ | ____ | ____ |
| **Social/Behavioral Sciences (3 SH)** | | | |
| ______________________________ | ____ | ____ | ____ |
| **Natural Sciences* ( 12 SH)** | | | |
| BIOL 1361/1161 Intro to Biological Science | ____ | ____ | ____ |
| CHEM 1331/1111 Fund of Chem & Lab | ____ | ____ | ____ |
| PHYS 1301/1121 Intro to General Phy & Lab | ____ | ____ | ____ |

**COLLEGE AND DEPARTMENT REQUIREMENTS (25 SH)**

| | GR | SH | AH |
|---|---|---|---|
| ELET 2300 Intro to C++ programming | ____ | ____ | ____ |
| ITEC 2334 Information Systems Apps | ____ | ____ | ____ |
| TELS 3340 Org Leadership & Suprv or HDCS 3300 Org Decisions in Tech | ____ | ____ | ____ |
| TELS 3363 Technical Communication | ____ | ____ | ____ |
| **Math Reasoning (9 SH)**** | | | |
| MATH 1330 Precalculus | ____ | ____ | ____ |
| MATH 1431 Elements of Calculus | ____ | ____ | ____ |
| TMTH 3360 Applied Tech Statistics or PSYC 3301 | ____ | ____ | ____ |

** Students are required to have credit for College Algebra through the Math Placement Exam, CLEP or completion of the course.

*Refer to class schedule for lists of courses which satisfy University requirements.

**36 advanced** (3000- or 4000-level) semester hours must be completed.
Total hours required: 122-123 semester hours
Texas Success Initiative requirements must be met.

**MAJOR CORE REQUIREMENTS (42 SH)**

| | GR | SH | AH |
|---|---|---|---|
| BIOL 1362/1162 Intro to Biological Science | ____ | ____ | ____ |
| CHEM 1332/1112 Fund of Chem & Lab | ____ | ____ | ____ |
| BIOL 2333/2133 Elem Microbiology & lab | ____ | ____ | ____ |
| BTEC 2320 Biotechnology Regulatory Env | ____ | ____ | ____ |
| BTEC 2321 Good Manufacturing Practices | ____ | ____ | ____ |
| BTEC 1322 Introduction to Biotechnology | ____ | ____ | ____ |
| BCHS 3304/3201 Gen Biochemistry & Lab | ____ | ____ | ____ |
| BIOL 3301 Genetics | ____ | ____ | ____ |
| BTEC 3100 Biotech Reserach Methods Lab | ____ | ____ | ____ |
| BTEC 3301 Prin of Bioinform/Geon/Proteom | ____ | ____ | ____ |
| CHEM 3221 Organic Chemistry Lab | ____ | ____ | ____ |
| CHEM 3331 Fund of Organic Chemistry | ____ | ____ | ____ |
| BIOL 4320 Molecular Biology | ____ | ____ | ____ |
| BTEC 4350 Capstone Experience | ____ | ____ | ____ |

**Choose either the Biomanufacturing or Bioinformatics Track.**

**Biomanufacturing Track (13 SH Minimum)**

| | GR | SH | AH |
|---|---|---|---|
| BTEC 3320 Intro QA/QC Drugs & Biologics | ____ | ____ | ____ |
| BIOL 4319 Microbial Genetics | ____ | ____ | ____ |
| BTEC 4301 Principles of Bioprocessing | ____ | ____ | ____ |
| BTEC 4101 Principles of Bioprocessing Lab | ____ | ____ | ____ |
| **Approved Elective(3SH)____________ | ____ | ____ | ____ |

**Bioinformatics Track (12 SH Minimum)**

| | GR | SH | AH |
|---|---|---|---|
| ITEC 3343 System Analysis & Design | ____ | ____ | ____ |
| ITEC 3365 Database Design | ____ | ____ | ____ |
| BTEC 4300 Prin of Bioinformatics | ____ | ____ | ____ |
| **Approved Elective (3SH)____________ | ____ | ____ | ____ |

****Electives to be chosen from approved list.**

**Approved Electives:**
BCHS 4306 Nucleic Acid
BIOL 4323 Immunology
BIOL 4374 Cell Biology
TELS 4350 Industrial & Environmental Safety

For graduation with Honors, see Undergraduate Catalog.

**APPROVALS:**

______________________________
Student Signature Date

______________________________
Advisor Date

______________________________
Department Chair Date

## Appendix B: Student Assessment of Learning Gains (SALG) Assessment Tool

Please complete as applicable.

**The class Overall**

| 1. HOW MUCH did the following aspects | **No help** | **a little help** | **moderate help** | **much help** | **great help** | **not applicable** |
|---|---|---|---|---|---|---|
| 1.1 The instructional approach taken in this class | | | | | | |
| 1.2 How the class topics, activities, reading and assignments fit together | | | | | | |
| 1.3 The pace of the class | | | | | | |
| 1.4 Please comment on how the INSTRUCTIONAL APRROACH to this class helped your learning<br>1.5 How has this class CHANGED THE WAYS YOU LEARN/STUDY? | | | | | | |
| | | | | | | |
| **Class Activities** | | | | | | |
| 2. HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING? | **No help** | **a little help** | **moderate help** | **much help** | **great help** | **not applicable** |
| 2.1 Attending lectures | | | | | | |
| 2.2 Participating in discussions during class | | | | | | |
| 2.3 Listening to discussion during class | | | | | | |
| 2.4 Participating in group work during class | | | | | | |
| 2.5 Doing hands-on classroom activities | | | | | | |
| | | | | | | |

| 2.6 Specific Class Activities | **No help** | **A little help** | **Moderate help** | **Much help** | **Great help** | **Not applicable** |
|---|---|---|---|---|---|---|
| 2.6.1 Class Activity 1 | | | | | | |
| 2.6.2 Class Activity 2 | | | | | | |
| 2.6.3 Class Activity 3 | | | | | | |
| 2.7 Please comment on how the CLASS ACTIVITIES helped your learning | | | | | | |
| 2.8 Please comment on HOW OFTEN YOU PARTICIPATED in class discussions and HOW THE ATMOSPHERE IN THE CLASSROOM ENCOURAGED OR DISCOURAGED your participation | | | | | | |
| | | | | | | |
| **Assignments, graded activities and tests** | | | | | | |
| 3. HOW MUCH did each of the following aspects of the class HELP YOU learning? | **No help** | **a little help** | **moderate help** | **much help** | **great help** | **not applicable** |
| 3.1 Graded assignments (overall) in this class | | | | | | |
| 3.2 Writing assignments (overall) | | | | | | |
| 3.2.1 Writing assignment 1 (Fill in) | | | | | | |
| 3.2.2 Writing assignment 2 (Fill in) | | | | | | |
| 3.2.3 Writing assignment 3 (Fill in) | | | | | | |
| 3.3 Other graded assignments | | | | | | |
| 3.3.1 Assignment 1 (Fill in) | | | | | | |
| 3.3.2 Assignment 2 (Fill in) | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 3.3.3 Assignment 3 (Fill in) | | | | | | |
| 3.4 Graded group projects | | | | | | |
| 3.5 Opportunities for in-class review (given by instructor or TA) | | | | | | |
| 3.6 The number and spacing of tests | | | | | | |
| 3.7 The fit between class content and test | | | | | | |
| 3.8 The mental stretch required by tests | | | | | | |
| 3.9 The way the grading system helped me understand what I needed to work on | | | | | | |
| 3.10 The feedback on my work received after tests or assignments | | | | | | |
| 3.11 Please comment on how the GRADED ACTIVITIES AND TESTS helped you learning | | | | | | |
| | | | | | | |
| **Class Resources** | | | | | | |
| 4. HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING? | **No help** | **a little help** | **moderate help** | **much help** | **great help** | **not applicable** |
| 4.1 The primary textbook | | | | | | |
| 4.2 Other reading material | | | | | | |
| 4.2.1 Reading Material 1 (Fill in) | | | | | | |
| 4.2.2 Reading Material 2 (Fill in) | | | | | | |
| 4.2.3 Reading Material 1 (Fill in) | | | | | | |
| 4.3 Online materials (other than teacher provided online notes or presentations) | | | | | | |
| 4.4 Online notes or presentations posted by instructor | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 4.5 Visual resources used in class (i.e. PowerPoint, Slides, models, demonstrations) | | | | | | |
| 4.6 Please comment on how the RESOURCES in this class helped your learning | | | | | | |
| | | | | | | |
| **The information you were given** | | | | | | |
| 5. HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING? | **No help** | **a little help** | **moderate help** | **much help** | **great help** | **not applicable** |
| 5.1 Explanation of how the class activities, reading and assignments related to each other | | | | | | |
| 5.2 Explanation given by instructor of how to learn or study the materials | | | | | | |
| 5.3 Explanation of why the class focused on the topics presented | | | | | | |
| 5.4 Please comment on HOW the INFORMATION YOU RECEIVED about the class helped you learning | | | | | | |
| | | | | | | |
| **Support for you as an individual learner** | | | | | | |
| 6. HOW MUCH did each of the following aspects of the class HELP YOUR LEARNING | **No help** | **a little help** | **moderate help** | **much help** | **great help** | **not applicable** |
| | | | | | | |
| 6.1Interacting with the instructor during office hours | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 6.2 Working with teaching assistants during the class | | | | | | |
| 6.3 Working with teaching assistants outside the class | | | | | | |
| 6.4 Working with peers during class | | | | | | |
| 6.5Working with peers outside of class | | | | | | |
| 6.6 Please comment on how the SUPPORT YOU RECEIVED FROM OTHERS helped your learning in this class | | | | | | |
| | | | | | | |
| **Your understanding of class content** | | | | | | |
| 7. As a result of your work in this class, what GAINS DID YOU MAKE in your UNDERSTANDING of each of the following | **No help** | **a little help** | **moderate help** | **much help** | **great help** | **not applicable** |
| 7.1 The main concepts explained in this class | | | | | | |
| 7.2 The relationships between the main concepts | | | | | | |
| 7.3 The following concepts that have been explored in this class | **No help** | **a little help** | **moderate help** | **much help** | **great help** | **not applicable** |
| 7.3.1 (Concept 1) (Fill in) | | | | | | |
| 7.3.2 (Concept 2) (Fill in) | | | | | | |
| 7.3.3 (Concept 3) (Fill in) | | | | | | |
| 7.4 How ideas from this class relate to ideas encountered in other classes within this subject area | | | | | | |
| | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 7.5 How ideas from this class relate to ideas encountered in classes outside of this subject area | | | | | | |
| 7.6 How studying this subject area helps people address real world issues | | | | | | |
| 7.7 Please comment on HOW YOUR UNDERSTANDING OF THE SUBJECT HAS CHANGED as a result of this class | | | | | | |
| 7.8 Please comment on how THE WAY THIS CLASS WAS TAUGHT helps you REMEMBER key ideas. | | | | | | |
| | | | | | | |
| **Increase in your skills** | | | | | | |
| 8. As a result of your work in this class, what GAINS DID YOU MAKE in the following SKILLS? | **no help** | **a little help** | **moderate help** | **much help** | **great help** | **not applicable** |
| 8.1 Finding articles relevant to a particular problem in professional journals or elsewhere | | | | | | |
| 8.2 Critically reading articles about issues raised in class | | | | | | |
| 8.3 Identifying patterns in data | | | | | | |
| 8.4 Recognizing a sound argument and appropriate use of evidence | | | | | | |
| 8.5 Developing a logical argument | | | | | | |
| 8.6 Writing documents in discipline-appropriate style and format | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 8.7 Working effectively with others | | | | | | |
| 8.8 Preparing and giving oral presentations | | | | | | |
| 8.9 Please comment on what SKILLS you have gained as a result of this class | | | | | | |
| | | | | | | |
| **Class impact on your attitudes** | | | | | | |
| 9. As a result of your work in this class, what GAINS DID YOU MAKE in the following? | **no help** | **a little help** | **moderate help** | **much help** | **great help** | **not applicable** |
| 9.1 Enthusiasm for the subject | | | | | | |
| 9.2 Interest in discussing the subject area with friends or family | | | | | | |
| 9.3 Interest in taking or planning to take additional classes in this subject | | | | | | |
| 9.4 Confidence that you understand the material | | | | | | |
| 9.5 Confidence that you can do this subject | | | | | | |
| 9.6 Your comfort level in working with complex ideas | | | | | | |
| 9.7 Willing to seek help from others (teacher, peers, TA) when working on academic problems | | | | | | |
| 9.8 Please comment on how has this class CHANGED YOUR ATTITUDES toward this subject | | | | | | |

| 10. As a result of your work in this class, what GAINS DID YOU MAKE in INTEGRATING the following? | **no help** | **a little help** | **moderate help** | **much help** | **great help** | **not applicable** |
|---|---|---|---|---|---|---|
| 10.1 Connecting key class ideas with other knowledge | | | | | | |
| 10.2 Applying what I learned in this class in other situations | | | | | | |
| 10.3 Using systematic reasoning in my approach to problems | | | | | | |
| 10.4 Using a critical approach to analyzing data and arguments in my daily life | | | | | | |
| 10.5 What will you CARRY WITH YOU into other classes or other aspects of your life? | | | | | | |

### Appendix C: Student Assessment Learning Gains Results for Module I and II, Fall 2008

| | Comments | No Help | A little Help | Moderate Help | Much help | Great help | Not appl |
|---|---|---|---|---|---|---|---|
| Item 1.1 | | | | | 43% | 57% | |
| Item 1.2 | | | | | 29% | 71% | |
| Item 1.3 | | | | | 29% | 71% | |
| Item 1.4 | The teaching assistants were helpful as was the hands-on approach to learning. Multiple-instructors was a benefit in this case. It would help to receive the packets the week prior to get a better feel for what to do. | | | | | | |
| Item 1.5 | The depth of the class as well as the hands on learning has created a good learning environment. | | | | | | |
| Item 2.1 | | | | | 14% | 86% | |
| Item 2.2 | | | | 14% | 14% | 71% | |
| Item 2.3 | | | | | 29% | 71% | |
| Item 2.4 | | | | | 14% | 86% | |
| Item 2.5 | | | | 14% | | 86% | |
| Item 2.6.1 | | | | 29% | | 43% | 14% |
| Item 2.6.2 | | | | 14% | 14% | 43% | 14% |
| Item 2.6.3 | | | | 14% | 14% | 43% | 14% |
| Item 2.7 | Course activities, especially the hands-on group activities, were very helpful. | | | | | | |

| | Comments | No Help | A little Help | Moderate Help | Much help | Great help | Not appl |
|---|---|---|---|---|---|---|---|
| Item 2.8 | The small classes encouraged participation by students. The instructor created a relaxed but professional atmosphere where students felt comfortable participating. | | | | | | |
| Item 3.1 | | | | 14% | 29% | 57% | |
| Item 3.2.1 | | | | 14% | | 71% | 14% |
| Item 3.2.2 | | | | | 14% | 43% | 29% |
| Item 3.2.3 | | | | | | 43% | 29% |
| Item 3.3.1 | | | | | 14% | 71% | 14% |
| Item 3.3.2 | | | | 14% | | 43% | 29% |
| Item 3.3.3 | | | | | 14% | 43% | 29% |
| Item 3.4 | | | | | 29% | 57% | 14% |
| Item 3.5 | | | | | 29% | 57% | |
| Item 3.6 | | | 14% | 14% | | 71% | |
| Item 3.7 | | | 14% | 14% | | 71% | |
| Item 3.8 | | | | 29% | 14% | 57% | |
| Item 3.9 | | | | 14% | 14% | 57% | 14% |
| Item 3.10 | | | | 14% | 14% | 71% | |
| Item 3.11 | The assessments ( e.g. quizzes and exams) served as good exercises to reinforce learning and study habits. | | | | | | |
| Item 4.1 | | 14% | | | | 14% | 71% |
| Item 4.2.1 | | | | | | 57% | 43% |

| | **Comments** | **No Help** | **A little Help** | **Moderate Help** | **Much help** | **Great help** | **Not appl** |
|---|---|---|---|---|---|---|---|
| Item 4.2.2 | | | | | | 43% | 43% |
| Item 4.2.3 | | | | | | 43% | 43% |
| Item 4.3 | | | | | 29% | 43% | |
| Item 4.4 | | | | | 14% | 57% | 29% |
| Item 4.5 | | | | | 14% | 57% | 14% |
| Item 4.6 | The PowerPoint presentation and lab notebook were excellent tools for learning. However, more references would be helpful as additional resources. | | | | | | |
| Item 5.1 | | | | 14% | | 86% | |
| Item 5.2 | | | | 14% | 14% | 71% | |
| Item 5.3 | | | | | 29% | 71% | |
| Item 5.4 | Course material was tied together coherently and tied the lectures to lab activities. | | | | | | |
| Item 6.1 | | | | | | 100% | |
| Item 6.2 | | | 14% | | 14% | 71% | |
| Item 6.3 | | | | | 14% | 86% | |
| Item 6.4 | | | | | | 71% | 29% |
| Item 6.5 | | | | | | 100% | |
| Item 6.6 | | | | | | 100% | |
| Item 6.7 | Class and peer support was generally good. However, one student did not see much help. | | | | | | |

| | Comments | No Help | A little Help | Moderate Help | Much help | Great help | Not appl |
|---|---|---|---|---|---|---|---|
| Item 7.1 | | | | | 14% | 86% | |
| Item 7.2 | | | | | 14% | 86% | |
| Item 7.3.1 | | | | | 14% | 43% | 29% |
| Item 7.3.2 | | | | | 14% | 43% | 29% |
| Item 7.3.3 | | | | | 14% | 43% | 29% |
| Item 7.4 | | | | | 14% | 71% | |
| Item 7.5 | | | | | 14% | 71% | |
| Item 7.6 | | | | | 29% | 57% | |
| Item 7.7 | One student pointed to an increased understanding of OPD and OPH. | | | | | | |
| Item 7.8 | The lecture and lab served as mutual reinforcement of course material. Class activities were also useful. | | | | | | |
| Item 8.1 | | | | 14% | 14% | 43% | 14% |
| Item 8.2 | | | | | 14% | 71% | |
| Item 8.3 | | | | 14% | 14% | 43% | 14% |
| Item 8.4 | | | | | 29% | 57% | |
| Item 8.5 | | | | 14% | 14% | 57% | |
| Item 8.6 | | | | 14% | 29% | 43% | |
| Item 8.7 | | | | | | 86% | |
| Item 8.8 | | | | | | 86% | |
| Item 8.9 | Students cited lab skills, research skills, and presentation skills as the main gains. | | | | | | |
| Item 9.1 | | | | | 14% | 71% | |

| | Comments | No Help | A little Help | Moderate Help | Much help | Great help | Not appl |
|---|---|---|---|---|---|---|---|
| Item 9.2 | | | | | 14% | 71% | |
| Item 9.3 | | | | | | 86% | |
| Item 9.4 | | | | | | 86% | |
| Item 9.5 | | | | | 14% | 86% | |
| Item 9.6 | | | | | 14% | 86% | |
| Item 9.7 | | | | | | 100% | |
| Item 9.8 | Students have credited this class with getting them more excited and interested in biotech. | | | | | | |
| Item 10.1 | | | | | | 100% | |
| Item 10.2 | | | | | 14% | 86% | |
| Item 10.3 | | | | | 14% | 86% | |
| Item 10.4 | | | | | 29% | 71% | |
| Item 10.5 | Students feel they will be able to translate several skills (including writing lab reports, public speaking, and research skills into other courses). | | | | | | |

**Appendix D : Student Assessment of Learning Gains for Module III, Spring 2009**

| | Comments | No Help | A little Help | Moderate Help | Much help | Great help | Not appl |
|---|---|---|---|---|---|---|---|
| Item 1.1 | | | | | | 100% | |
| Item 1.2 | | | | | | 100% | |
| Item 1.3 | | | | | | 100% | |
| Item 1.4/1.5 | The instructions and open-ended questions were very helpful. Excellent class for beginners in the field. | | | | | | |
| Item 2.1 | | | | | | 100% | |
| Item 2.2 | | | | | | 100% | |
| Item 2.3 | | | | | | 100% | |
| Item 2.4 | | | | | 33% | 66% | |
| Item 2.5 | | | | | | 100% | |
| Item 2.6.1 | | | | | 33% | 66% | |
| Item 2.6.2 | | | | | | 100% | |
| Item 2.6.3 | | | | | | 100% | |
| Item 2.7/2.8 | | | | | | | |
| Item 3.1 | | | | | | 100% | |
| Item 3.2 | | | | | | 100% | |
| Item 3.2.1 | | | | | | 66% | |
| Item 3.2.2 | | | | | | 66% | |
| Item 3.2.3 | | | | | | 66% | |

| | Comments | No Help | A little Help | Moderate Help | Much help | Great help | Not appl |
|---|---|---|---|---|---|---|---|
| Item 3.3 | | | | | 33% | 66% | |
| Item 3.3.1 | | | | | 33% | 66% | |
| Item 3.3.2 | | | | | | 100% | |
| Item 3.3.3 | | | | | | 100% | |
| Item 3.4 | | | | | | 100% | |
| Item 3.5 | | | | | | 100% | |
| Item 3.6 | | | | | | 100% | |
| Item 3.7 | | | | | | 100% | |
| Item 3.8 | | | | | | 100% | |
| Item 3.9 | | | | | | 100% | |
| Item 3.10 | | | | | | 100% | |
| Item 3.11 | | | | | | | |
| Item 4.1 | | | | | | 66% | |
| Item 4.2 | | | | | 33% | 55% | |
| Item 4.2.1 | | | | | 33% | 66% | |
| Item 4.2.2 | | | | | | 100% | |
| Item 4.2.3 | | | | | | 100% | |
| Item 4.3 | | | | | | 66% | |
| Item 4.4 | | | | 33% | | 66% | |
| Item 4.5 | | | | | 33% | 66% | |
| Item 4.6 | | | | | | | |
| Item 5.1 | | | | | 33% | 66% | |
| Item 5.2 | | | | | | 100% | |
| Item 5.3 | | | | | | 100% | |

| | Comments | No Help | A little Help | Moderate Help | Much help | Great help | Not appl |
|---|---|---|---|---|---|---|---|
| Item 5.4 | | | | | | 100% | |
| Item 6.1 | | | | | | 100% | |
| Item 6.2 | | | | | | 100% | |
| Item 6.3 | | | | | | 100% | |
| Item 6.4 | | | | | 33% | 66% | |
| Item 6.5 | | | | | | 66% | |
| Item 6.6 | | | | | | | |
| Item 7.1 | | | | | | 100% | |
| Item 7.2 | | | | | | 100% | |
| Item 7.3.1 | | | | | | 100% | |
| Item 7.3.2 | | | | | | 100% | |
| Item 7.3.3 | | | | | | 66% | |
| Item 7.4 | | | | 33% | | 66% | |
| Item 7.5 | | | | | | 66% | |
| Item 7.6 | | | | 33% | | 66% | |
| Item 7.7 | | | | | | | |
| Item 7.8 | | | | | | | |
| Item 8.1 | | | | 66% | | 33% | |
| Item 8.2 | | | | 33% | | 33% | 33% |
| Item 8.3 | | | | 33% | | 66% | |
| Item 8.4 | | | | 33% | | 33% | 33% |
| Item 8.5 | | | | 33% | 33% | 33% | |
| Item 8.6 | | | | 33% | 33% | 33% | |
| Item 8.7 | | | | 33% | 33% | 33% | |

| | Comments | No Help | A little Help | Moderate Help | Much help | Great help | Not appl |
|---|---|---|---|---|---|---|---|
| Item 8.8 | | | | 33% | | 33% | 33% |
| Item 8.9 | | | | | | | |
| Item 9.1 | | | | 33% | | 66% | |
| Item 9.2 | | | | 33% | | 66% | |
| Item 9.3 | | | | | | 100% | |
| Item 9.4 | | | | | 33% | 66% | |
| Item 9.5 | | | | | 33% | 66% | |
| Item 9.6 | | | | | | 100% | |
| Item 9.7 | | | | | | 100% | |
| Item 9.8 | | | | | | | |
| Item 10.1 | | | | 33% | | 66% | |
| Item 10.2 | | | | | 33% | 66% | |
| Item 10.3 | | | | | 33% | 66% | |
| Item 10.4 | | | | | | 66% | 33% |
| Item 10.5 | | | | | | | |