Applications of Biotechnology

Course Description: This course further introduces students to the fundamentals of biotechnology. Included in this course are additional applications and techniques in biotechnology, which expand and increase the student's comprehension of how biotechnology utilizes living systems to create products and enhance lives. Further, laboratory applications learned in this course form the pivotal component distinguishing science theory from its application in bioscience much like that of engineering and mathematics. Bioscience and the application of laboratory technique to the manipulation of living systems is a cornerstone of pharmaceutical, medical device, forensic science, environmental science, agriculture, alternative fuel, and green chemistry.

Prerequisites: Introduction to Biotechnology. For students in the Healthcare Science Career Pathway Biotechnology Research and Development: Introduction to Healthcare Science, Introduction to Biotechnology

Major Concepts/Skills	**Concepts/Skills to Maintain**
Science underlying biotechnological technique Biological understanding Mathematical underpinnings of living systems Biosafety in laboratory settings Society and biotechnology Regulatory systems	Characteristics of Science Records investigations clearly and accurately Uses scientific tools Interprets graphs, tables, and charts Writes clearly Uses proper units Organizes data into graphs, tables, and charts Analyzes scientific data via calculations and inference Uses models Asks quality questions Uses technology Uses safety techniques Recognizes the importance of explaining data with precision and accuracy

Co-requisite – Content

HS-ABT-1. Students will describe how characteristics of living organisms are integrated with advanced biotechnology techniques to lead to discovery or production.

a. Describe how cell membrane structure may be manipulated to allow passage of macromolecules, including electroporation, microprojectile and ionic stress.

b. Demonstrate how DNA structure and function may be exploited in genetic engineering to produce specific genetic constructs.
    - Engineer nucleic acids through selecting, excising, ligating and cloning of plasmid or viral vectors for development of molecular delivery systems.
    - Simulate enzymatic replication of nucleic acids utilizing real-time or traditional PCR including primer design.
    - Isolate and prepare DNA samples for sequencing.
    - Manage and analyze DNA sequence data using bioinformatics tools (*e.g.* Genbank and BLAST).

c. Relate principles of macromolecule structure, physical chemistry and composition to strategies for isolating, analyzing and characterizing protein and DNA.
    - Perform methods of protein extraction and purification such as salt precipitation and dialysis, chromatography or antibody purification.
    - Design and perform methods of protein measurement, quantification, and characterization such as: Western blot, polyacrylamide gel electrophoresis, ELISA, and UV/VIS spectrophotometry (*e.g.* as used in simulated testing and confirming of samples as hepatitis B and Lyme disease).
    - Apply the principles of electricity and ionization to successfully migrate charged molecules in ionic buffering systems.
    - Describe principles of phase separation in physical chemistry used in high performance liquid chromatography (HPLC) and gas chromatography (GC) for separating mixed analytes.

d. Apply the basic concepts of cell growth and homeostatsis to systems for culturing cells.
    - Describe the different cell types and culture methods (*e.g.*, bacteria, yeast, animal and plant) as used in biotechnology.
    - Review sterile culture technique and apply it to growing eukaryotic cells in culture (*e.g.*, plant cell culture).
    - Distinguish between the culture environments needed for single-celled organisms and cells from multicellular organisms.

Academic Standards:
SB1 Students will analyze the nature of the relationships between structures and functions in living cells.

SB2. Students will analyze how biological traits are passed on to successive generations.
a. Distinguish between DNA and RNA.
b. Explain the role of DNA in storing and transmitting cellular information.

SB3 Students will derive the relationship between single-celled and multi-celled organisms and the increasing complexity of systems.

SB4 Students will assess the dependence of all organisms on one another and the flow of energy and matter within their ecosystems.

SCSh3 Students will identify and investigate problems scientifically.

SCSh4 Students use tools and instruments for observing, measuring, and manipulating scientific equipment and materials.

SCSh5 Students will demonstrate the computation and estimation skills necessary for analyzing data and developing reasonable scientific explanations.

SCSh6. Students will communicate scientific investigations and information clearly.

SC7 Students will characterize the properties that describe solutions and the nature of acids and bases.

SCSh8 Students will understand important features of the process of scientific inquiry.

SPS10 Students will investigate the properties of electricity and magnetism.

MM1A1 Students will explore and interpret the characteristics of functions, using graphs, tables, and simple algebraic techniques.

MM1D3 Students will relate samples to a population.

MM1P1 Students will solve problems (using appropriate technology).

MM1P4 Students will make connections among mathematical ideas and to other disciplines.

MM1P5 Students will represent mathematics in multiple ways.

MM2D2 Students will determine an algebraic model to quantify the association between two quantitative variables.

HS-ABT-2. Students will demonstrate how advanced techniques in biotechnology contribute to our quality of life.

a. Describe how biotechnology has contributed to the advancement of biology impacting human well-being, such as disease management through vaccines, food production, materials science and molecular identification.
b. Apply biotechnological techniques to forensics including materials analysis, DNA fingerprinting and sample collection.
c. Utilize biotechnology for healthcare applications.
    - Utilize biotechnology for diagnostic applications (*e.g.* hepatitis, HIV, BRAC, rapid streptococcus).

- Explain the role of biotechnology in therapeutics (*e.g.*, gene therapy, vaccines. antibody therapy, cell therapy).
- Describe how bioinformatics can be used to predict disease and determine treatment.
- Investigate the principles of genetic mapping applied to healthcare or phylogenetics and evolution (*e.g.*, AFLP, RFLP, SNPs, etc.).

d. Describe the non-medical applications of biotechnology including enzyme production, biofuel and biomaterials discovery and manufacturing.

Academic Standards:

SCSh1 Students will evaluate the importance of curiosity, honesty, openness, and skepticism in science.

SCSh3 Students will identify and investigate problems scientifically.

SCSh4 Students use tools and instruments for observing, measuring, and manipulating scientific equipment and materials.

SCSh5 Students will demonstrate the computation and estimation skills necessary for analyzing data and developing reasonable scientific explanations.

ELA10C1 The student demonstrates understanding and control of the rules of the English language, realizing that usage involves the appropriate application of conventions and grammar in both written and spoken formats.

ELA10LSV1(d) Actively solicits another person's comments or opinion. (e) Offers own opinion forcefully without domineering.

MM1D3 Students will relate samples to a population.

HS-ABT-3. Students will utilize statistical analyses to evaluate molecular separations and manipulations.

a. Discuss the importance of appropriate controls, standards, and statistical planning in laboratory applications and experimental design.
b. Assess the quality of data including possible sources of bias in their investigations' hypotheses, observations, data analyses, and interpretations.
c. Compare the standard deviation and the mean of efficacy testing data of two or more biotechnology products.
d. Apply linear regression to calibration curves in UV/Vis spectrophotometry and ELISA.
e. Represent data using Gaussian distributions (normal populations).
f. Explain the reliability of data and construct confidence intervals for pH measurements and pipetting accuracy.

g. Establish measurement parameters and accuracy determination for real-time PCR and HPLC or GC detection data interpretation.
h. Apply significant figures to laboratory assessments and calculations to fall within established criteria.

Academic Standards:

ELA9RC2 The student participates in discussions related to curricular learning in all subject areas.

ELA9LSV1 The student participates in student-to-teacher, student-to-student, and group verbal interactions.

ELA9RL5 The student understands and acquires new vocabulary and uses it correctly in reading and writing.

ELA11W3 The student uses research and technology to support writing.

MM1A1 Students will explore and interpret the characteristics of functions, using graphs, tables, and simple algebraic techniques.

MM1P1 Students will solve problems (using appropriate technology).

MM1P4 Students will make connections among mathematical ideas and to other disciplines.

MM1P5 Students will represent mathematics in multiple ways.

MM2D1 Using sample data, students will make formal inferences about population means and standard deviation.

MM1D3 Students will relate samples to a population.

SCSh4 Students use tools and instruments for observing, measuring, and manipulating scientific equipment and materials.

SCSh5 Students will demonstrate the computation and estimation skills necessary for analyzing data and developing reasonable scientific explanations.

HS-ABT-4. Students will incorporate required safety practices and procedures in performing tasks encountered in the laboratory setting.

a. Apply laboratory safety techniques to electrophoresis, microbiological manipulations and biological sample handling.

b. Analyze case studies of lab accidents and biohazards in various settings. (Examples include dangers of gases, explosions, electrical shock, biohazards, infectious disease, and genetically modified organisms; also other topics as suggested by current events.)
c. Demonstrate ways to prevent or manage lab accidents and biohazards in various workplace settings.
d. Understand and apply safe methods for transporting chemicals, grounding electrical equipment, sharps disposal, monitoring gas pressures (pressurized tanks), and using secondary containment systems for transport (safe shipping methods).
e. Describe Biosafety Levels 1, 2, 3 and 4 (BSL1, BSL 2, BSL3 and BSL4) and the facility design associated with each level.
f. Understand laminar flow, and the purpose of biosafety cabinets relative to managing biological hazards.

Academic Standard:

SCSh2 Students will use standard safety practices for all classroom laboratory and workplace investigations.
a. Follow correct procedures for use of scientific apparatus.
b. Demonstrate appropriate technique in all laboratory situations.
c. Follow correct protocol for identifying and reporting safety problems and violations.

HS-ABT-5. Students will demonstrate an understanding of current trends, ethical, legal, and regulatory issues related to the development of biotechnology products.

a. Monitor scientific journals, Internet sources, mass media and industry associations to identify current trends and policy issues in biotechnology.
b. Distinguish between marketing material and experimentally validated information.
c. Describe the concept of integrity and the ethical use of statistics, controls, and standards.
d. Apply knowledge of bioethical/legal issues to various scenarios, including clinical trials, Institutional Review Boards (IRB) applications, privacy (HIPAA), choice of genetic traits, and use of genetic testing data.
e. Describe intellectual property rights, technology transfer and how biotechnology is funded.
f. Explain the meaning of human dignity and informed consent in biotechnology and healthcare.
g. Describe the role of federal regulatory agencies and the Code of Federal Regulations applicable to biotechnology *(e.g.*, FDA, 21 CFR, EPA, NIH, USDA, etc.) and the relationship to international regulatory systems (*e.g.*, ICH, etc.).
h. Explain the phases of clinical trials and requirements for obtaining FDA product approval.
i. Define the purpose of quality assurance, quality control, method validation, documentation, current Good Manufacturing Practices and Good Laboratory Practices.
j. Document and keep accurate records according to regulatory requirements.

Academic Standards:

ELA11W3 The student uses research and technology to support writing.

SCSh1. Students will evaluate the importance of curiosity, honesty, openness, and skepticism in science.
a. Exhibit the above traits in their own scientific activities.
b. Recognize that different explanations often can be given for the same evidence.
c. Explain that further understanding of scientific problems relies on the design and execution of new experiments which may reinforce or weaken opposing explanations.

SCSh3. Students will identify and investigate problems scientifically.
a. Suggest reasonable hypotheses for identified problems.
b. Develop procedures for solving scientific problems.
c. Collect, organize and record appropriate data.

SCSh5. Students will demonstrate the computation and estimation skills necessary for analyzing data and developing reasonable scientific explanations.
a. Trace the source on any large disparity between estimated and calculated answers to problems.
b. Consider possible effects of measurement errors on calculations.
c. Recognize the relationship between accuracy and precision.
d. Express appropriate numbers of significant figures for calculated data, using scientific notation where appropriate.
e. Solve scientific problems by substituting quantitative values, using dimensional analysis and/or simple algebraic formulas as appropriate.

SCSh6. Students will communicate scientific investigations and information clearly.
a. Write clear, coherent laboratory reports related to scientific investigations.
b. Write clear, coherent accounts of current scientific issues, including possible alternative interpretations of the data.
c. Use data as evidence to support scientific arguments and claims in written or oral presentations.
d. Participate in group discussions of scientific investigation and current scientific issues.

SCSh9. Students will enhance reading in all curriculum areas.

SSEF4 The student will compare and contrast different economic systems, and explain how they answer the three basic economic questions of what to produce, how to produce and for whom to produce.

MM1P1 Students will solve problems (using appropriate technology).

MM1P4 Students will make connections among mathematical ideas and to other disciplines.

MM1P5 Students will represent mathematics in multiple ways.

Co-Requisite – Characteristics of Science

Habits of Mind

SCSh1. Students will evaluate the importance of curiosity, honesty, openness, and skepticism in science.

a. Exhibit the above traits in their own scientific activities.

b. Recognize that different explanations often can be given for the same evidence.

c. Explain that further understanding of scientific problems relies on the design and execution of new experiments which may reinforce or weaken opposing explanations.

SCSh2. Students will use standard safety practices for all classroom laboratory and field investigations.

a. Follow correct procedures for use of scientific apparatus.

b. Demonstrate appropriate technique in all laboratory situations.

c. Follow correct protocol for identifying and reporting safety problems and violations.

SCSh3. Students will identify and investigate problems scientifically.

a. Suggest reasonable hypotheses for identified problems.

b. Develop procedures for solving scientific problems.

c. Collect, organize and record appropriate data.

d. Graphically compare and analyze data points and/or summary statistics.

e. Develop reasonable conclusions based on data collected.

f. Evaluate whether conclusions are reasonable by reviewing the process and checking against other available information.

SCSh4. Students use tools and instruments for observing, measuring, and manipulating scientific equipment and materials.

a. Develop and use systematic procedures for recording and organizing information.

b. Use technology to produce tables and graphs.

c. Use technology to develop, test, and revise experimental or mathematical models.

SCSh5. Students will demonstrate the computation and estimation skills necessary for analyzing data and developing reasonable scientific explanations.

a. Trace the source on any large disparity between estimated and calculated answers to problems.

b. Consider possible effects of measurement errors on calculations.

c. Recognize the relationship between accuracy and precision.

d. Express appropriate numbers of significant figures for calculated data, using scientific notation where appropriate.

e. Solve scientific problems by substituting quantitative values, using dimensional analysis and/or simple algebraic formulas as appropriate.

SCSh6. Students will communicate scientific investigations and information clearly.

a. Write clear, coherent laboratory reports related to scientific investigations.

b. Write clear, coherent accounts of current scientific issues, including possible alternative interpretations of the data.

c. Use data as evidence to support scientific arguments and claims in written or oral presentations.

d. Participate in group discussions of scientific investigation and current scientific issues.

The Nature of Science

SCSh7. Students analyze how scientific knowledge is developed.

Students recognize that:

a. The universe is a vast single system in which the basic principles are the same everywhere.

b. Universal principles are discovered through observation and experimental verification.

c. From time to time, major shifts occur in the scientific view of how the world works. More often, however, the changes that take place in the body of scientific knowledge are small modifications of

prior knowledge. Major shifts in scientific views typically occur after the observation of a new phenomenon or an insightful interpretation of existing data by an individual or research group.

d. Hypotheses often cause scientists to develop new experiments that produce additional data.

e. Testing, revising, and occasionally rejecting new and old theories never ends.

SCSh8. Students will understand important features of the process of scientific inquiry.

Students will apply the following to inquiry learning practices:

a. Scientific investigators control the conditions of their experiments in order to produce valuable data.

b. Scientific researchers are expected to critically assess the quality of data including possible sources of bias in their investigations' hypotheses, observations, data analyses, and interpretations.

c. Scientists use practices such as peer review and publication to reinforce the integrity of scientific activity and reporting.

d. The merit of a new theory is judged by how well scientific data are explained by the new theory.

e. The ultimate goal of science is to develop an understanding of the natural universe which is free of biases.

f. Science disciplines and traditions differ from one another in what is studied, techniques used, and outcomes sought.

Reading Standard Comment
After the elementary years, students are seriously engaged in reading for learning. This process sweeps across all disciplinary domains, extending even to the area of personal learning. Students encounter a variety of informational as well as fictional texts, and they experience text in all genres and modes of discourse. In the study of various disciplines of learning (English language arts, mathematics, science, social studies), students must learn through reading the communities of discourse of each of those disciplines. Each subject has its own specific vocabulary, and for students to excel in all subjects, they must learn the specific vocabulary of those subject areas *in context.* Beginning with the middle grades years, students begin to self-select reading materials based on personal interests established through classroom learning. Students become curious about science, mathematics, history, and literature as they form contexts for those subjects related to their personal and classroom experiences. As students explore academic areas through reading, they develop favorite subjects and become confident in their verbal discourse about those subjects.
Reading across curriculum content develops both academic and personal interests in students. As students read, they develop both content and contextual vocabulary. They also build good habits for

reading, researching, and learning. The Reading Across the Curriculum standard focuses on the academic and personal skills students acquire as they read in all areas of learning.

SCSh9. Students will enhance reading in all curriculum areas by:

a. Reading in all curriculum areas

Read both informational and fictional texts in a variety of genres and modes of discourse.

Read technical texts related to various subject areas.

b. Discussing books

Discuss messages and themes from books in all subject areas.

Respond to a variety of texts in multiple modes of discourse.

Relate messages and themes from one subject area to messages and themes in another area.

Evaluate the merit of texts in every subject discipline.

Examine author's purpose in writing.

Recognize the features of disciplinary texts.

c. Building vocabulary knowledge

Demonstrate an understanding of contextual vocabulary in various subjects.

Use content vocabulary in writing and speaking.

Explore understanding of new words found in subject area texts.

d. Establishing context

Explore life experiences related to subject area content.

Discuss in both writing and speaking how certain words are subject area related.

Determine strategies for finding content and contextual meaning for unknown words.

CTAE Foundation Skills

The Foundation Skills for Career, Technical and Agricultural Education (CTAE) are critical competencies that students pursuing any career pathway should exhibit to be successful. As core

standards for all career pathways in all program concentrations, these skills link career, technical and agricultural education to the state's academic performance standards.
The CTAE Foundation Skills are aligned to the foundation of the U. S. Department of Education's 16 Career Clusters. Endorsed by the National Career Technical Education Foundation (NCTEF) and the National Association of State Directors of Career Technical Education Consortium (NASDCTEC), the foundation skills were developed from an analysis of all pathways in the sixteen occupational areas. These standards were identified and validated by a national advisory group of employers, secondary and postsecondary educators, labor associations, and other stakeholders. The Knowledge and Skills provide learners a broad foundation for managing lifelong learning and career transitions in a rapidly changing economy.

CTAE-FS-1 Technical Skills: Learners achieve technical content skills necessary to pursue the full range of careers for all pathways in the program concentration.

CTAE-FS-2 Academic Foundations: Learners achieve state academic standards at or above grade level.

CTAE-FS-3 Communications: Learners use various communication skills in expressing and interpreting information.

CTAE-FS-4 Problem Solving and Critical Thinking: Learners define and solve problems, and use problem-solving and improvement methods and tools.

CTAE-FS-5 Information Technology Applications: Learners use multiple information technology devices to access, organize, process, transmit, and communicate information.

CTAE-FS-6 Systems: Learners understand a variety of organizational structures and functions.

CTAE-FS-7 Safety, Health and Environment: Learners employ safety, health and environmental management systems in corporations and comprehend their importance to organizational performance and regulatory compliance.

CTAE-FS-8 Leadership and Teamwork: Learners apply leadership and teamwork skills in collaborating with others to accomplish organizational goals and objectives.

CTAE-FS-9 Ethics and Legal Responsibilities: Learners commit to work ethics, behavior, and legal responsibilities in the workplace.

CTAE-FS-10 Career Development: Learners plan and manage academic-career plans and employment relations.

CTAE-FS-11 Entrepreneurship: Learners demonstrate understanding of concepts, processes, and behaviors associated with successful entrepreneurial performance.