Biotechnology

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Office of the State Superintendent of Education
Postsecondary and Career Education Division
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The purpose of this document is to communicate the required Career and Technical Education (CTE) academic standards for the Biotechnology Program of Study. The academic standards in this document are theoretical and performance-based. The standards contain content from Colorado, Maryland, Tennessee, and Texas and were validated by D.C. business and industry partners. All content is used with permission.

In addition to academic standards, OSSE has incorporated into this document Labor Market Information (LMI) definitions and explanations for the Program of Study; program aligned Industry Recognized Credentials; and Work-Based Learning resources and requirements by course level.

This document is intended for use by educational administrators and practitioners. A similar document is available for each state-approved CTE Program of Study.

Biotechnology

Table of Contents

Course Descriptions: Biotechnology		
Course Level	**Course Information**	**Description**
Level I	**Principles of Biosciences** **OSSEID:** 5080201 **Grades:** 9-12 **Prerequisite:** None **Credit:** 1	Principles of Biosciences is a strong reinforcement of Biology content that provides an overview of biotechnology, bioengineering, and related fields. Topics include genetics, cell structure, proteins, nucleic acids, and the impact of immunological events in biotechnology. Students will further study the increasingly important agricultural, environmental, economic, and political roles of bioenergy and biological remediation; the roles of nanoscience and nanotechnology in biotechnology medical research; and future trends in biological science and biotechnology.
Level II	**Biotechnology I** **OSSEID:** 5080202 **Grades:** 10-12 **Prerequisite:** Principles of Biosciences **Credit:** 1	In Biotechnology I, students will apply advanced academic knowledge and skills to the emerging fields of biotechnology such as agricultural, medical, regulatory, and forensics. Students will have the opportunity to use sophisticated laboratory equipment, perform statistical analysis, and practice quality-control techniques. Students will conduct laboratory and field investigations, use scientific methods during investigations, and make informed decisions using critical thinking and scientific problem-solving. Students in Biotechnology I will study a variety of topics that include structures and functions of cells, nucleic acids, proteins, and genetics.
Level III	**Biotechnology II** **Practice OSSEID:** 5080203 **Grades:** 11-12 **Prerequisite:** Biotechnology I **Credit:** 1	Biotechnology II has the components of any rigorous scientific or bioengineering program of study from the problem identification, investigation design, data collection, data analysis, and formulation and presentation of the conclusions. This course applies the standard skills mastered in Biotechnology I and includes assay design. After taking this course, students should be prepared for entry-level lab technician jobs.
Level IV	**Practicum in Health Science: Biotechnology** **OSSEID:** 5080204 **Grades:** 12 **Prerequisite:** Biotechnology II **Credit:** 1	The Practicum in Health Science course is designed to give students practical application of previously studied knowledge and skills. Practicum experiences can occur in a variety of locations appropriate to the nature and level of experience.

Industry Certifications

Work-Based Learning Examples and Resources

Level I Course	Level II Course	Level III Course	Level IV Course
Career Exploration Industry Visits Guest Speakers Participate in a CTSO	**Career Awareness** *All of Level I, plus:* Postsecondary Visits Program-Specific Site Tours Mock Interviews	**Career Preparation** *All of Level I and II, plus:* Job Shadow Paid/Unpaid Internships	**Career Preparation** Paid/Unpaid Internships Apprenticeships

Several resources are available to help instructors meet the Level I and Level II WBL requirements, including:

Career Coach DC (http://careercoachdc.emsicc.com). Online site designed to help students find and connect to a career pathway by providing the most current local data on wages, employment, job postings, and associated education and training. The resource includes a Career Assessment for students.

Nepris (https://dc.nepris.com/). Connects educators and learners with a network of industry professionals virtually, bringing real-world relevance and career exposure to all students. Nepris also provides a skills-based volunteering platform for business and industry professionals to extend their educational outreach.

Virtual Job Shadow (https://virtualjobshadow.com). Provides interactive tools which empower students to discover, plan, and pursue their dreams. Rich video library presents a "day in the life of" view for thousands of occupations.

Labor Market Information Definitions and Data

Career and Technical Education programs of study in the District of Columbia must meet at least one of the High Wage, High Skill, and In-Demand definitions below to be considered appropriate for our students and the regional labor market. These definitions were created in collaboration with Career and Technical Education leaders from District of Columbia LEA's, the University of the District of Columbia Community College, and national guidance from Research Triangle International (RTI) and Education Northwest. Additionally, previous work was consulted from researchers at MIT's Labor Wage Index Project and the DC CTE Task Force's 2012 Strategic Plan for the District of Columbia.

Indicator	Definition	Data for the Biotechnology Program of Study (source: EMSI, August 2021)
High Wage	Those occupations that have a 25th percentile wage equal to or greater than the most recent MIT Living Wage Index for one adult in the District of Columbia, and/or leads to a position that pays at least the median hourly or annual wage for the Washington, DC, metropolitan statistical area. *Note: A 25th percentile hourly wage of $20.49 or greater is required to meet this definition.*	**Standard Occupational Code (SOC):** 19-4021.00 Biological Technician 19-1029.00 Biological Scientists, All Other **Hourly Wages** **25th Percentile:** $30.58 **50th Percentile:** $39.30 **75th Percentile:** $50.823
High Skill	Those occupations located within the Washington, DC, metropolitan statistical area with the following education or training requirements: completion of an apprenticeship program; completion of an industry-recognized certification or credential; associate's degree, or higher.	**Typical Entry-Level Education:** Bachelor's Degree
In-Demand	Those occupations in the Washington, DC, metropolitan statistical area having more than the median number of total **(growth plus replacement)** annual openings over a five-year period. *Note: An occupation is required to have an annual growth plus replacement rate of 105 openings, or greater, between 2020-25 to meet this definition.*	**Annual Openings:** 327

Model Six-Year Plan: Biotechnology

College: University of the District of Columbia Community College
Program/CIP:
Plan:

Entity: Office of the State Superintendent of Education
Career Cluster: Health Science
Program of Study: Biotechnology

High School					College			
Subject	**9th Grade**	**10th Grade**	**11th Grade**	**12th Grade**	**Semester I**	**Semester II**	**Semester III**	**Semester IV**
English (4)	English I	English II	English III	English IV				
Math (4)	Algebra I	Geometry	Algebra II	Math				
Science (4)	Biology	Lab Science	Anatomy and Physiology	Science				
Social Studies (4)	World History and Geography I: Middle Ages	World History and Geography II: Modern World	U.S. History	U.S. Government (.5) and D.C. History (.5)				
Health (.5) and Physical Ed (1)	Health (.5) Physical Ed (.5)	Physical Ed (.5)						
World Languages (2)			World Language I	World Language II				
Art (.5)		Art (.5)						
Music (.5)		Music (.5)						
Elective / Major Courses	Principles of Biosciences	Biotechnology I	Biotechnology II	Practicum in Health Science: Biotechnology				
Total possible college credits completed in high school: XX					***Credit hours required to complete the AAS program: XX***			

Course Standards

Principles of Biosciences

1. **General requirements.** This course is recommended for students in Grades 9 through 12. Students shall be awarded one credit for successful completion of this course.

2. **Introduction.**
   A. Career and technical education instruction provides content aligned with challenging academic standards and relevant technical knowledge and skills for students to further their education and succeed in current or emerging professions.

   B. The Health Science Career Cluster focuses on planning, managing, and providing therapeutic services, diagnostics services, health informatics, support services, and biotechnology research and development.

   C. Principles of Biosciences is a strong reinforcement of Biology content that provides an overview of biotechnology, bioengineering, and related fields. Topics include genetics, cell structure, proteins, nucleic acids, and the impact of immunological events in biotechnology. Students will further study the increasingly important agricultural, environmental, economic, and political roles of bioenergy and biological remediation; the roles of nanoscience and nanotechnology in biotechnology medical research; and future trends in biological science and biotechnology.

   D. Students will participate in at least two Career Exploration Work-Based Learning experiences in this course, which might include guest speakers and workplace tours relevant to the program of study.

   E. Students are encouraged to participate in extended learning experiences such as career and technical student organizations and other leadership or extracurricular organizations.

3. **Knowledge and skills.**
   A. **The student demonstrates professional standards/employability skills as required by business and industry. The student is expected to:**
      1. demonstrate knowledge of how to dress appropriately, speak politely, and conduct oneself in a manner appropriate for the profession;
      2. show the ability to cooperate, contribute, and collaborate as a member of a group in an effort to achieve a positive collective outcome;
      3. present written and oral communication in a clear, concise, and effective manner;
      4. demonstrate time-management skills in prioritizing tasks, following schedules, and performing goal-relevant activities in a way that produces efficient results; and
      5. demonstrate punctuality, dependability, reliability, and responsibility in performing assigned tasks as directed.

B. **The student explores biotechnology career opportunities. The student is expected to:**
   1. determine interests and aptitudes through conversations with biotechnology professionals;
   2. identify career options in the field of biotechnology;
   3. identify reliable sources of career information;
   4. research interests, knowledge, educational level, abilities, and skills needed in a biotechnology-related occupation;
   5. seek a mentor in the biotechnology area;
   6. identify conventional and non-conventional career opportunities that match interests and aptitudes; research applications of biotechnology and biomaterials such as the areas of medicine and the environment and pharmaceutical, agricultural, and industrial settings; and
   7. use technology to research biotechnology topics, identify pertinent scientific articles, obtain articles of interest, and write a formal research paper in the format used by academic and professional journals and magazines.

C. **The student evaluates ethical and legal issues in biotechnology. The student is expected to:**
   1. identify current ethical and legal issues;
   2. describe the history of biotechnology and related current issues;
   3. discuss legal and technology issues for at least two biotechnology related areas; and
   4. compare and contrast examples of objective and subjective scientific, economic, and political data and positions used to defend biotechnology views.

D. **The student examines federal, state, local, and industry regulations as applied to biotechnical processes through library research and Internet research. The student is expected to:**
   1. identify local, state, and federal agencies responsible for regulating the biotechnology industry;
   2. identify professional organizations participating in the development of biotechnology policies;
   3. identify and define terms related to biotechnology regulations; and
   4. outline the methods and procedures used in biotechnology laboratories to follow and enforce local, state, and federal regulations such as those in the agricultural and health areas.

E. **The student demonstrates knowledge of the business climate for biotechnology industry sectors in the current market. The student is expected to:**
   1. identify professional publications;
   2. identify the various biotechnology industry sectors; and
   3. investigate and report on career opportunities in the biotechnology industry sectors.

F. **The student researches and exhibits employability skills that support a career in the biotechnology industry. The student is expected to:**
   1. demonstrate verbal, nonverbal, written, and electronic communication skills;
   2. demonstrate skills used to secure and maintain employment;
   3. demonstrate appropriate workplace etiquette; and
   4. display productive work habits and attitudes.

G. **The student investigates the origins of waste and examines the relationship of biotechnology to resource recovery. The student is expected to:**
   1. investigate at least three end products from biotechnology manufacturing processes;
   2. investigate the effects of waste on environmental and biological life cycles;
   3. investigate the impacts of waste on the environment;
   4. analyze the results of manufacturing refuse;
   5. explain the negative impacts of waste with respect to the individual, society, and the global population;
   6. research solutions to biological waste with respect to commercial applications through investigation of various pollution waste treatments using natural organisms;
   7. investigate biotechnology as it relates to health and well-being; and
   8. cite evidence regarding regulations, patents and public policy, design development and testing, and safety.

H. **The student examines the relationship of biotechnology to the development of commercial products. The student is expected to:**
   1. identify the ability to change or enhance genetic characteristics;
   2. identify applications of genetic engineering;
   3. identify applications of nanotechnology in biotechnology;
   4. identify applications of bioinformatics in biotechnology;
   5. identify the applications of biotechnology in fields such as medicine, forensics, and law enforcement; and
   6. research ethical considerations, laws, and regulations governing genetic engineering and nanotechnology.

I. **The student develops technology skills. The student is expected to:**
   1. use technology as a tool to research, organize, evaluate, and communicate information.
   2. use digital technologies (computers, PDAs, media players, GPSs, etc.); communication/networking tools, and social networks appropriately to access, manage; integrate, evaluate, and create information to successfully function in a knowledge economy;
   3. demonstrate using current and new technologies specific to the program of study, course; and/or industry; and
   4. apply a fundamental understanding of the ethical/legal issues surrounding the access and use of information technologies.

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Biotechnology I

1. **General requirements.** This course is recommended for students in Grades 10 thought 12. Prerequisite: Principles of Biotechnology. Students shall be awarded one credit for successful completion of this course.

2. **Introduction.**
   A. Career and technical education instruction provides content aligned with challenging academic standards and relevant technical knowledge and skills for students to further their education and succeed in current or emerging professions.

   B. The Health Science Career Cluster focuses on planning, managing, and providing therapeutic services, diagnostics services, health informatics, support services, and biotechnology research and development.

   C. In Biotechnology I, students will apply advanced academic knowledge and skills to the emerging fields of biotechnology such as agricultural, medical, regulatory, and forensics. Students will have the opportunity to use sophisticated laboratory equipment, perform statistical analysis, and practice quality-control techniques. Students will conduct laboratory and field investigations, use scientific methods during investigations, and make informed decisions using critical thinking and scientific problem solving. Students in Biotechnology I will study a variety of topics that include structures and functions of cells, nucleic acids, proteins, and genetics.

   D. Students will participate in at least two Career Awareness Work-Based Learning experiences in this course, which might include informational interviews or job shadowing relevant to the program of study.

   E. Students are encouraged to participate in extended learning experiences such as career and technical student organizations and other leadership or extracurricular organizations.

3. **Knowledge and skills.**
   A. **The student demonstrates professional standards/employability skills as required by business and industry. The student is expected to:**
      1. demonstrate knowledge of how to dress appropriately, speak politely, and conduct oneself in a manner appropriate for the profession;
      2. show the ability to cooperate, contribute, and collaborate as a member of a group in an effort to achieve a positive collective outcome;
      3. present written and oral communication in a clear, concise, and effective manner;
      4. demonstrate time-management skills in prioritizing tasks, following schedules, and performing goal-relevant activities in a way that produces efficient results; and
      5. demonstrate punctuality, dependability, reliability, and responsibility in performing assigned tasks as directed.

B. **The student, for at least 40% of instructional time, conducts laboratory and field investigations using safe, environmentally appropriate, and ethical practices. These investigations must involve actively obtaining and analyzing data with physical equipment, but may also involve experimentation in a simulated environment as well as field observations that extend beyond the classroom. The student is expected to:**

1. demonstrate safe practices during laboratory and field investigations, including chemical, electrical, and fire safety, and safe handling of live and preserved organisms;
2. demonstrate an understanding of the use and conservation of resources and the proper disposal or recycling of materials;
3. demonstrate appropriate safety procedures, guidelines, and chemical hygiene plan;
4. maintain required safety training, including location and understanding of interpretation of safety data sheets;
5. comply with federal and state safety regulations as specified by Occupational Safety and Health Administration (OSHA) and other regulatory agencies as appropriate;
6. identify and obey safety symbols and signs;
7. maintain clean and well organized work areas;
8. dispose of equipment, glassware, and biologics according to laboratory policies;
9. recognize common laboratory hazards;
10. observe procedures for the safe use of instruments, gas cylinders, and chemicals; and
11. maintain safety and personal protection equipment.

C. **The student uses scientific methods and equipment during laboratory and field investigations. The student is expected to:**

1. know the definition of science and understand that it has limitations, as specified in subsection (b)(4) of this section;
2. know that hypotheses are tentative and testable statements that must be capable of being supported or not supported by observational evidence. Hypotheses of durable explanatory power which have been tested over a wide variety of conditions are incorporated into theories;
3. know that scientific theories are based on natural and physical phenomena and are capable of being tested by multiple independent researchers. Unlike hypotheses, scientific theories are well-established and highly-reliable explanations, but they may be subject to change as new areas of science and new technologies are developed;
4. distinguish between scientific hypotheses and scientific theories;
5. plan and implement investigative procedures, including asking questions, formulating testable hypotheses, and selecting, handling, and maintaining appropriate equipment and technology;
6. collect data individually or collaboratively, make measurements with precision and accuracy, record values using appropriate units, and calculate statistically relevant quantities to describe data, including mean, median, and range;
7. demonstrate the use of course apparatus, equipment, techniques, and procedures;
8. organize, analyze, evaluate, build models, make inferences, and predict trends from data;
9. perform calculations using dimensional analysis, significant digits, and scientific notation; and
10. communicate valid conclusions using essential vocabulary and multiple modes of expression such as lab reports, labeled drawings, graphic organizers, journals, summaries, oral reports, and technology-based reports.

D. **The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions within and outside the classroom. The student is expected to:**
   1. in all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing, including examining all sides of scientific evidence of those scientific explanations, so as to encourage critical thinking;
   2. communicate and apply scientific information extracted from various sources such as current events, news reports, published journal articles, and marketing materials;
   3. draw inferences based on data related to promotional materials for products and services;
   4. evaluate the impact of research and technology on scientific thought, society, and the environment;
   5. evaluate models according to their limitations in representing biological objects or events;
   6. describe the connection between biotechnology and future careers; and
   7. research and describe the history of biotechnology and contributions of scientists.

E. **The student explores the emerging field of biotechnology. The student is expected to:**
   1. define biotechnology and provide examples of biotechnology products such as recombinant proteins, fermented foods, biopharmaceuticals, and genetically modified foods;
   2. explore applications of bioinformatics such as deoxyribonucleic acid (DNA) barcoding, phylogenetic relationships, and the use of online databases;
   3. research career opportunities in fields such as molecular, forensic, medical, regulatory, and agricultural biotechnology;
   4. research the history of biotechnology and contributions of scientists;
   5. define bioethics and research applications of bioethics;
   6. research applications in agricultural biotechnology such as tissue culturing, genetically modified foods, plant propagation, and hydroponics; and
   7. research applications in medical biotechnology such as vaccines, stem cells, microarrays, and pharmaceutical production.

F. **The student summarizes biotechnology laboratory procedures and their applications in the biotechnology industry. The student is expected to:**
   1. identify the major sectors of the biotechnology industry;
   2. categorize the biotechnology laboratory procedures included in each sector; and
   3. compare the different applications used in biotechnology laboratory procedures of each sector.

G. **The student understands the role of genetics in the biotechnology industry. The student is expected to:**
   1. explain terms related to molecular biology including nucleic acids, nitrogen bases, amino acids, transcription, translation, polymerase, and protein synthesis;
   2. describe the structure and function of deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) in cells and viruses;
   3. compare and contrast the nitrogen bases of DNA and RNA;
   4. explain how nucleotides join together to form a DNA double helix;
      a. describe the DNA replication process in eukaryotic and prokaryotic cells;
   5. illustrate the process of protein synthesis; and
   6. describe the structure and function of proteins, including 3D folding, enzymes, and antibodies.

H. **The student analyzes the importance of recombinant DNA technology and genetic engineering. The student is expected to:**
1. describe the fundamental steps in recombinant DNA technology;
2. explain how recombinant DNA technology is used to clone genes and create recombinant proteins;
3. explain the role of tissue cultures to genetic modification procedures;
4. describe plant- and animal-tissue culture procedures;
5. compare and contrast proper growing conditions for plant and animal tissue cultures;
6. explain the role of restriction enzymes;
7. distinguish among vectors commonly used in biotechnology for DNA insertion, including plasmids, retroviruses, and bacteriophages; and
8. explain the steps and components of the polymerase chain reaction.

I. **The student examines federal, state, local, and industry regulations as related to biotechnology. The student is expected to:**
1. discuss the relationship between the local, state, and federal agencies responsible for regulation of the biotechnology industry; and
2. analyze policies and procedures used in the biotechnology industry such as quality assurance, standard operating procedures (SOPs), *Good Manufacturing Practices* (GMPs), and International Organization for Standardization (ISO) quality systems.

J. **The student performs standard biotechnology laboratory procedures. The student is expected to:**
1. identify and operate laboratory equipment, including a microscope, thermocycler, hood, pH meter, hot plate stirrer, balance, mixers, autoclave, power supply, micropipette, centrifuge, and electrophoresis unit;
2. practice measuring volumes and weights to industry standards;
3. analyze data and perform calculations and statistical analysis as it relates to biotechnology laboratory experiments;
4. demonstrate proficiency pipetting techniques;
5. identify microorganisms using staining methods such as the Gram stain, methylene-blue stain, and acid-fast staining;
6. document laboratory results; and
7. prepare a restriction digest and analyze results using gel electrophoresis.

K. **The student prepares solutions and reagents for the biotechnology laboratory. The student is expected to:**
1. demonstrate techniques for establishing and maintaining a sterile work area;
2. prepare, dispense, and monitor physical properties of stock reagents, buffers, media, and solutions;
3. calculate and prepare a dilution series; and
4. determine optimum conditions of reagents for experimentation.

L. **The student performs advanced biotechnology laboratory procedures. The student is expected to:**
1. explain the importance of media components to the outcome of cultures;
2. isolate, maintain, and store microbial cultures safely;
3. prepare seed inoculum;
4. perform plating techniques such as the Kirby-Bauer method;

5. analyze proteins using techniques such as enzyme-linked immunosorbent assay (ELISA), spectrophotometry, and sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE);
6. isolate a specific protein from a biological sample using chromatography;
7. isolate nucleic acids and interpret gel electrophoresis results;
8. perform a bacterial transformation and analyze gene expression; and
9. amplify a DNA sequence using the polymerase chain reactions.

M. **The student conducts quality-control analysis while performing biotechnology laboratory procedures. The student is expected to:**
   1. perform validation testing on laboratory reagents and equipment; and
   2. analyze data and perform calculations and statistical analysis on results of quality-control samples such as trending of data.

N. **The student develops technology skills. The student is expected to:**
   1. Use technology as a tool to research, organize, evaluate, and communicate information.
   2. Use digital technologies (computers, PDAs, media players, GPSs, etc.); communication/networking tools,
   3. and social networks appropriately to access, manage; integrate, evaluate, and create information to
   4. successfully function in a knowledge economy;
   5. Demonstrate using current and new technologies specific to the program of study, course; and/or
   6. industry; and
   7. Apply a fundamental understanding of the ethical/legal issues surrounding the access and use of information technologies.

Biotechnology II

1. **General requirements.** This course is recommended for students in Grades 11 and 12. Prerequisites: Biotechnology I. Students must meet the 40% laboratory and fieldwork requirement. Students shall be awarded one credit for successful completion of this course.

2. **Introduction.**
   A. Career and technical education instruction provides content aligned with challenging academic standards and relevant technical knowledge and skills for students to further their education and succeed in current or emerging professions.

   B. The Health Science Career Cluster focuses on planning, managing, and providing therapeutic services, diagnostics services, health informatics, support services, and biotechnology research and development.

   C. Biotechnology II has the components of any rigorous scientific or bioengineering program of study from the problem identification, investigation design, data collection, data analysis, and formulation and presentation of the conclusions. This course applies the standard skills mastered in Biotechnology I and includes assay design. After taking this course, students should be prepared for entry-level lab technician jobs.

   D. Students will participate in a Career Preparation Work-Based Learning experience in this course, which might include paid or unpaid internship experiences relevant to the program of study.

   E. Students are encouraged to participate in extended learning experiences such as career and technical student organizations and other leadership or extracurricular organizations.

3. **Knowledge and skills.**
   A. **The student demonstrates professional standards/employability skills as required by business and industry. The student is expected to:**
      1. demonstrate knowledge of how to dress appropriately, speak politely, and conduct oneself in a manner appropriate for the profession;
      2. show the ability to cooperate, contribute, and collaborate as a member of a group in an effort to achieve a positive collective outcome;
      3. present written and oral communication in a clear, concise, and effective manner;
      4. demonstrate time-management skills in prioritizing tasks, following schedules, and performing goal-relevant activities in a way that produces efficient results; and
      5. demonstrate punctuality, dependability, reliability, and responsibility in performing assigned tasks as directed.

   B. **The student, for at least 40% of instructional time, conducts laboratory and field investigations using safe, environmentally appropriate, and ethical practices. These investigations must involve actively obtaining and analyzing data with physical equipment, but may also involve experimentation in a simulated environment as well as field observations that extend beyond the classroom. The student is expected to:**
      1. demonstrate safe practices during laboratory and field investigations; and

C. demonstrate an understanding of the use and conservation of resources and the proper disposal or recycling of materials.

D. **The student uses scientific methods and equipment during laboratory and field investigations. The student is expected to:**
   1. know the definition of science and understand that it has limitations, as specified in subsection (b)(4) of this section;
   2. know that scientific hypotheses are tentative and testable statements that must be capable of being supported or not supported by observational evidence. Hypotheses of durable explanatory power which have been tested over a wide variety of conditions are incorporated into theories;
   3. know that scientific theories are based on natural and physical phenomena and are capable of being tested by multiple independent researchers. Unlike hypotheses, scientific theories are well-established and highly-reliable explanations, but may be subject to change as new areas of science and new technologies are developed;
   4. distinguish between scientific hypotheses and scientific theories;
   5. plan and implement investigative procedures, including making observations, asking well-defined questions, formulating testable hypotheses, identifying variables, selecting appropriate equipment and technology, and evaluating numerical answers for reasonableness;
   6. collect and organize qualitative and quantitative data and make measurements with accuracy and precision using tools such as calculators, spreadsheet software, data-collecting probes, computers, standard laboratory glassware, microscopes, various prepared slides, stereoscopes, metric rulers, electronic balances, gel electrophoresis apparatuses, micropipettors, hand lenses, Celsius thermometers, hot plates, lab notebooks or journals, timing devices, cameras, and meter sticks;
   7. analyze, evaluate, make inferences, and predict trends from data;
   8. identify and quantify causes and effects of uncertainties in measured data;
   9. organize and evaluate data and make inferences from data, including the use of tables, charts, and graphs; and
   10. communicate valid conclusions supported by the data through various methods such as lab reports, labeled drawings, graphic organizers, journals, summaries, oral reports, and technology-based reports.

E. **The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions within and outside the classroom. The student is expected to:**
   1. in all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing, including examining all sides of scientific evidence of those scientific explanations, so as to encourage critical thinking;
   2. communicate and apply scientific information extracted from various sources such as current events, news reports, published journal articles, and marketing materials;
   3. draw inferences based on data related to promotional materials for products and services;
   4. explain the impacts of the scientific contributions of a variety of historical and contemporary scientists on scientific thought and society;
   5. evaluate models according to their limitations in representing biological objects or events;
   6. research and describe the connections between science and future careers; and
   7. express and interpret relationships symbolically to make predictions and solve problems mathematically, including problems requiring proportional reasoning and graphical vector addition.

F. **The student formulates hypotheses to guide investigation and data collection. The student is expected to:**
   1. perform background research with respect to an investigative problem; and
   2. examine hypotheses generated to guide a research process by evaluating the merits and feasibility of the hypotheses.

G. **The student analyzes published research. The student is expected to:**
   1. identify the scientific methodology used by a researcher;
   2. examine a prescribed research design and identify dependent and independent variables;
   3. evaluate a prescribed research design to determine the purpose for each of the procedures performed; and
   4. determine if the data and conclusion support the hypothesis.

H. **The student develops and implements appropriate investigative designs. The student is expected to:**
   1. interact and collaborate with scientific researchers or other members of the scientific community to complete a research project;
   2. identify and manipulate relevant variables within research situations;
   3. use a control in an experimental process; and
   4. design procedures to test hypotheses.

I. **The student collects, organizes, and evaluates qualitative and quantitative data obtained through experimentation. The student is expected to:**
   1. differentiate between qualitative and quantitative data;
   2. acquire, manipulate, and analyze data using appropriate equipment and technology, following the rules of significant digits;
   3. identify sources of random error and systematic error and differentiate between both types of error;
   4. report error of a set of measured data in various formats, including standard deviation and percent error;
   5. construct data tables to organize information collected in an experiment;
   6. record observations as they occur within an investigation; and
   7. evaluate data using statistical methods to recognize patterns, trends, and proportional relationships.

J. **The student knows how to synthesize valid conclusions from qualitative and quantitative data. The student is expected to:**
   1. synthesize and justify conclusions supported by research data;
   2. consider and communicate alternative explanations for observations and results; and
   3. identify limitations within the research process and provide recommendations for additional research.

K. **The student communicates conclusions clearly and concisely to an audience of professionals. The student is expected to:**
   1. communicate experimental results clearly and effectively, including oral presentation of original findings of a research project to an audience of peers and professionals; and
   2. suggest alternative explanations from observations or trends evident within the data or from prompts provided by a review panel.

L. **The student explores assay design in the field of biotechnology. The student is expected to:**
   1. define assay requirements and optimizations;

2. perform statistical analysis on assay design and experimental data such as linearity, system sustainability, limit of detection, and R2 values;
3. determine an unknown protein concentration using techniques such as a standard curve and a spectrophotometer; and
4. use a colorimetric assay to evaluate enzyme kinetics.

M. **The student explores protein expression systems in the field of biotechnology. The student is expected to:**
1. perform a recombinant protein production such as *green fluorescent protein* (GFP)
2. isolate a protein from a biological sample using hydrophobic interaction column chromatography; and
3. analyze protein purification methods using spectrophotometry, sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE) and Western blotting.

N. **The student conducts quality-control analysis while performing biotechnology laboratory procedures. The student is expected to:**
1. perform validation testing on laboratory reagents and equipment;
2. analyze data and perform calculations and statistical analysis on results of quality-control samples such as trending of data; and
3. apply and create industry protocols such as standard operating procedures (SOPs) and validation forms.

O. **The student prepares solutions and reagents for the biotechnology laboratory. The student is expected to:**
1. demonstrate techniques for establishing and maintaining a sterile work area;
2. prepare, dispense, and monitor physical properties of stock reagents, buffers, media, and solutions;
3. calculate and prepare a dilution series;
4. determine acceptability and optimum conditions of reagents for experimentation; and
5. prepare multi-component solutions of given molarity or concentration and volume.

O. **The student develops technology skills. The student is expected to:**
1. Use technology as a tool to research, organize, evaluate, and communicate information.
2. Use digital technologies (computers, PDAs, media players, GPSs, etc.); communication/networking tools,
3. and social networks appropriately to access, manage; integrate, evaluate, and create information to
4. successfully function in a knowledge economy;
5. Demonstrate using current and new technologies specific to the program of study, course; and/or
6. industry; and
7. Apply a fundamental understanding of the ethical/legal issues surrounding the access and use of information technologies.

Practicum in Health Science: Biotechnology

1. **General requirements.** This course is recommended for students in Grade 12. The practicum course is a paid or unpaid capstone experience for students participating in a coherent sequence of career and technical education courses in the Health Science Career Cluster. Prerequisite: Biotechnology II. Students shall be awarded one credit for successful completion of this course.

2. **Introduction.**
   A. Career and technical education instruction provides content aligned with challenging academic standards and relevant technical knowledge and skills for students to further their education and succeed in current or emerging professions.

   B. The Health Science Career Cluster focuses on planning, managing, and providing therapeutic services, diagnostic services, health informatics, support services, and biotechnology research and development.

   C. The Practicum in Health Science course is designed to give students practical application of previously studied knowledge and skills. Practicum experiences can occur in a variety of locations appropriate to the nature and level of experience.

   D. Students will participate in a Career Preparation Work-Based Learning experience in this course, which includes paid or unpaid internship, pre-apprenticeship, or apprenticeship experiences relevant to the program of study.

   E. Students are encouraged to participate in extended learning experiences such as career and technical student organizations and other leadership or extracurricular organizations.

3. **Knowledge and skills.**
   A. **The student demonstrates professional standards/employability skills as required by business and industry. The student is expected to:**
      1. demonstrate verbal and non-verbal communication in a clear, concise, and effective manner; and
      2. exhibit the ability to cooperate, contribute, and collaborate as a member of a team.

   B. **The student applies mathematics, science, English language arts, and social sciences in health science. The student is expected to:**
      1. interpret data from various sources in formulating conclusions;
      2. accurately report and compile information from a variety of sources to create a technical report;
      3. plan, prepare, and deliver a presentation;
      4. apply mathematical related skills in the biotechnology laboratory.

   C. **The student implements the knowledge and skills of a biotechnology professional necessary to acquire and retain employment. The student is expected to:**
      1. Demonstrate understanding of the scientific method and apply the principles of experimental design to basic laboratory protocols;
      2. develop new problem-solving strategies based on previous knowledge and skills; and
      3. evaluate performance for continuous improvement and advancement in the biosciences.

D. **The student employs ethical behavior standards and legal responsibilities. The student is expected to:**
   1. identify individual ethical and legal behavior standards according to professional regulatory agencies; and
   2. research case studies related to unethical behavior in the health care industry.

E. **The student employs a safe environment to prevent hazardous situations. The student is expected to:**
   1. integrate regulatory standards such as standard precautions for specimen handling;
   2. evaluate hazardous materials according to the material safety data sheets; and
   3. apply principles of infection control and body mechanics in all aspects of the biosciences industry;
   4. manipulate tools and technology according to industry standards and protocols.

F. **The student implements skills pertaining to one of the four areas of biotechnology:**
   1. medical;
   2. industrial;
   3. environmental; and/or
   4. agricultural.

G. **The student explores the knowledge and skill levels necessary for advancing in the biotechnology professions. The student is expected to:**
   1. identify knowledge and skills that are transferable among biotechnology professions; and
   2. research career pathways pertaining to the biosciences industry.

H. **The student recognizes the importance of participation in extended learning experiences. The student is expected to:**
   1. participate in extended learning experiences such as community service, career and technical student organizations, and professional organizations; and
   2. create a plan of action targeting the career and technical student organization's community service goal.

I. **The student develops technology skills. The student is expected to:**
   1. Use technology as a tool to research, organize, evaluate, and communicate information.
   2. Use digital technologies (computers, PDAs, media players, GPSs, etc.); communication/networking tools,
   3. and social networks appropriately to access, manage; integrate, evaluate, and create information to
   4. successfully function in a knowledge economy;
   5. Demonstrate using current and new technologies specific to the program of study, course; and/or
   6. industry; and
   7. Apply a fundamental understanding of the ethical/legal issues surrounding the access and use of information technologies.


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