



Title: Applied Chemistry and Biotechnology

Length of Course: Full Year (2 semesters; 3 trimesters; 4 quarters)

Subject Area and Discipline: Laboratory Science ("d") – Chemistry

CTE Sector: Health Science and Medical Technology

CTE Pathway: Biotechnology

Grade Level(s): 10

Course Overview:

This course allows students to investigate and apply chemistry and biotechnology concepts and methods to understand and address issues related to five essential human needs -- Water, Food, Health, Waste Management, and Energy -- as Chemistry and Biotechnology complement each other in addressing these essential needs. Human diseases, for example, are treated by either small molecule drugs produced by chemistry or protein-based drugs produced by biotechnology, and environmental contaminants can be cleaned up either using chemistry or microbes. Whether a chemistry or biotechnology solution works best depends on the specific nature of the problem, and often both approaches to the problem are necessary for optimal resolution.

In this course, students will study the methods necessary to test, clean, and protect our water resources, understand the molecular components and energy in their food, research genetically modified foods and their role in relation to health issues, environmental issues and farmer and consumer rights, investigate a human disease, evaluate common food and environmental substances that cause disease, analyze local flora for a potential drug develop to cure diseases, develop solutions to waste management problems and produce a usable fuel from a waste product produced by human activity. Throughout the course students will be required to research and develop solutions to threats in these areas of essential needs.

Students will be required to keep a formal laboratory notebook documenting their research, experimental design and process of testing, evaluating and re-testing their solutions as well as all mathematical calculations, and chemical and biotechnology concepts applied. Notebooks and products of each assignments (expert reports and industry recommendations, poster sessions, news articles and infographics) in each unit will be used by the teacher as assessments. The teacher will look for understanding of key concepts, application of this understanding and the ability to solve real world problems in each of the 5 areas of essential needs.

Course Content:

Unit 1 - Water Quality Testing

Driving question: "How can biotechnology and chemistry ensure a reliable supply of clean water?"

Students will study the methods necessary to test, clean, and protect our water resources. Project teams will build a molecular model of water to investigate inter- and intramolecular interactions in water. They will test "clean" water from the school site for various chemical compounds commonly found in water to understand the solution chemistry of water as a model system, to investigate pH and chemical equilibrium in a buffered chemical system and detect the presence of microorganisms. They will then collect "dirty" water samples from the school site and test them for contaminants to determine if organic, inorganic or microbial contaminants exist and devise a strategy for removing those contaminants. The results of the water tests will be reported in a formal lab report using good laboratory practices (GLP). Finally, students will use bioremediation to clean a water sample fouled with oil or heavy metals, report the results in a formal lab report and create a water quality report for their sample to submit to a water quality expert to evaluate.

Unit 1 - Assignments

1: Understanding water and water chemistry

Students will begin their study of water by building a molecular model to understand the intramolecular bonds and properties of this molecule. The understanding of this simple compound will help address the characteristics of clean water. Students will investigate the intermolecular interactions in pure water such as surface tension and capillary action and compare them to these properties in impure water. Students will collect "clean" water samples from their school site, research normal ranges for common chemicals found in clean water, and conduct chemical analyses to test pH and concentrations of dissolved oxygen, ammonia, nitrate, nitrite, phosphate, and salinity and use microbial assays to detect the presence of microorganisms in the laboratory. The results of the analyses will be reported in a formal lab report following good laboratory practice (GLP) for the chemical and biotech industries.

2: Analyzing and restoring water quality

- a. Students will begin by researching a water quality problem that is due to organic, inorganic or microbial contaminants and use the chemical and biological properties of the contaminant to explore potential corrective actions. They will investigate the chemical properties of the water contaminant and predict the effect it has on water quality due to altered chemical reactions or changes in chemical equilibrium. Using the results of their research, student teams, including a lead scientist and a materials scientist, will engage in the design of and conduct an experiment to solve this real-world problem. The experimental design must

include the use of antimicrobials, filtering or chemistry that will remove the contaminants from a sample of “dirty” water collected from the school site. The experimental design will include methods used in assignment #1 (testing for concentrations of chemical compounds, microbes and pH) and the results of the analysis of the “dirty water” will be compared to the results of the “clean “ water test in assignment #1

b. Because pH balance is a critical component of potable water, students will design a procedure to treat a sample of non-neutral water to restore the pH balance to neutral using a chemical or biological buffering system.

Experimental design and results for assignments 2a and 2b will be reported in a formal lab report.

3: In this assignment students will investigate natural ways of cleaning up the environment by using organisms such as microbes and plants, or bioremediation. Students will develop a process in which they use organisms to neutralize pollutants from a contaminated site in order to learn about the biochemistry of plants and microbes and skills needed to propagate plants and microbes. Students will research if the contaminants may be naturally occurring or caused by humans and will record and research the health risks and/or aesthetic problems associated with unclean water. Students will then study plant or microbial biochemical processes that can be harnessed to bioremediate water contaminants. Students will use the results of their research to design and carry out an experiment to remove a specific water contaminant using bioremediation. They will describe the results of the experiment and the implications for applications of bioremediation in a formal lab report.

4: Students will create a water quality report that summarizes the chemical and microbial composition of their water sample before and after anti-microbials, filtering or chemistry treatment (assignment 2a) and bioremediation (assignment 3). The report will include the levels of chemical compounds, pH and microbes tested for in assignments 1 & 2. The report will follow the format of a water quality reports used by a water quality agency and will be evaluated by water quality experts.

Unit 2 - Food

Driving Question: How do the disciplines of Chemistry and Biotechnology work together to address humans’ essential need for a safe and sustainable food supply?

In this unit students will investigate what is in their food. They will research genetically modified foods and their role in relation to health issues, environmental issues and farmer and consumer rights. Students will prepare a recommendation report to a legislator arguing for or against the use of genetic modifications in the manufacturing of food as well as recommendations for current food labeling legislation. After completing their research students will test foods to determine if they are genetically modified using a common biotech technique called polymerase chain reaction, which uses an enzyme to

amplify specific regions of DNA. Students will next investigate the nutritional content of their food by using chemical reagents as indicator solutions to test foods for the presence of specific macromolecules (proteins, carbohydrates and lipids) and test foods for energy content using thermochemistry and calorimetry. After evaluating data collected through multiple laboratory investigations students will create an infographic showing the ratio of nutrition to energy in natural and processed foods, infographic will be displayed in various locations on their school's campus.

Unit 2 - Assignments

1: Genetic Modifications Imposed on Foods

Students will take on the role of lobbyists who have opposing views on how food made from genetically modified organisms (GMOs) should be labelled. Students will conduct research to define GMOs and explain how genetically modified plants and animals differ from organic specimens. Students will research how GMOs are used in the manufacturing of the foods we eat and create a product of their choice for assessment (for example graphs, animation, posters, videos), using evidence from research to argue for or against the use of GMOs. In preparation for the vote on legislation about mandatory labeling laws for foods that contain GMOs, students will present, using formal debate protocol, the pros or cons of adding modifications to food in today's agricultural, environment and human health. Using sufficient evidence and scientific reasoning to defend and critique claims, students will create an advisory report to give to legislators. The report should include all biological and chemical information collected during the research phase related to health issues, environmental issues and farmer and consumer rights and a recommendation on how the legislator should vote on the GMO labelling bill and why.

2: The Building Blocks of Food

a. Students will use polymerase chain reaction (PCR) to detect the presence of the most common genetic modifications in food substances. Students will make calculations and prepare chemical solutions in order to isolate DNA from food substances and use the DNA as a template for a PCR experiment. The procedure will amplify regions of the DNA that have been modified in GMO's. Through the PCR procedure, students will gain an understanding of the structure and function of DNA and enzymes. Students will also investigate factors that affect their chemical reactions, kinetics, equilibria and structure like pH, salt concentration and temperature by optimizing the PCR reaction. Students will relate their understanding of the properties of the DNA molecule to how it behaves in the presence of an electric field by analyzing the results of the PCR using gel electrophoresis. The optimized procedure and the results will be reported in a lab notebook.

b. Students will research the use of indicator solutions commonly used in the biotech lab to test for the amounts of protein, carbohydrates, lipids and DNA and summarize the chemical reactions involved in the way the indicator solutions work.

They will then use indicator solutions to analyze the macromolecules in a natural food and its processed counterpart. Students will brainstorm natural/processed food pair possibilities and decide on one set of foods to analyze (ex. natural cheese and Velveeta). They will design an experiment to test for protein using Biuret reagent, starch using iodine, sugar using Benedict's solution, lipids using Sudan IV and DNA using DPA in their food pairs. Results of the research and the testing will be summarized in a lab notebook.

c. By analyzing the chemical properties of healthy food and its processed counterparts tested in Assignment #2b, students will now conduct a thermochemistry experiment using calorimetry to determine the amount of heat energy released in these foods and then present their data in terms of energy content (in kJ/g). Students will understand energy cannot be destroyed but can be converted to other forms of energy, such as thermal energy, by using calorimetry lab practices. Students will analyze energy content (in kJ/g) and compare data with the energy content values given on food labels (in Calories). Students will then calculate the ratio of nutrition to energy in the foods they tested and draw conclusions about which food, the natural or processed counterpart, is healthier. The experimental procedure including results and conclusions will be reported in a lab notebook.

d. After analyzing and interpreting shared class data collected from laboratory assignments 2a-c students will prepare an infographic that includes composition and nutritional data of natural food and its processed counterpart. Infographic will communicate scientific information and stress the importance of knowing the contents of the food you consume before putting it in your body. The infographic will include images of the food pairs tested, whether they are made from GMO's and the ratio of nutrition to energy for each food pair. The infographic will be displayed in the school's cafeteria, Health and Physical Education classes and other places on campus. The infographic is intended to help educate peers about the benefits of knowing what is in the food you consume and how that knowledge could inform food choices.

Unit 3 - Everyday Chemicals, Medicine and Human Health

In this unit students will focus on the role of Chemistry and Biotechnology in our knowledge of disease, treatment, and prevention. Students will understand how the disciplines of Chemistry and Biotechnology intersect to keep humans healthy by investigating a human disease, studying the relationship between protein conformation and disease, evaluating common food and environmental substances that cause disease, outlining steps for disease prevention, and analyzing local flora for potential drug development to cure diseases. Students will begin with a case study on diabetes and insulin, including causes and treatment, to illustrate how the knowledge of the chemical structure of insulin and use of biotechnology to manufacture insulin contributed to both the understanding and development of medical treatments for this disease. After studying the bonding that holds proteins in their secondary and tertiary structure and

related catalytic activity of an enzyme, students will apply their understanding of the molecular structures and reactivity of everyday substances and their interactions with biological systems in order to explain how chemicals may harm or benefit human health, with a focus on their effects on intermolecular and intramolecular bonding, protein conformation, and enzymatic activity. By comparing their experimental microbial assay results to known published results of these common chemical substances, students will discuss the role of model organisms in biotechnology research and manufacturing. Students will employ chemistry and biotechnology lab skills to isolate chemical compounds using thin layer chromatography and perform microbial assays in order describe the major steps involved in pharmaceutical product research and development. At the end of Unit 3, students will be able to articulate the interdependence of Chemistry and Biotechnology in and participate in advancing our understanding of disease, treatment, and prevention for improving human health.

Unit 3 - Assignments

1: Diabetes Case Study and History of Insulin

Students will examine a case study of a young girl with a family history of type 1 diabetes, and create a Family Health Portrait to document the disease through her family, assess her risk of developing the disease, and outline available treatments. Students will research the history of mapping and decoding the chemical structure of insulin, and subsequent use of biotechnology to manufacture insulin. Using the background and history of disease and treatment of diabetes, students will write a brief electronic news article describing the interdisciplinary roles of chemistry and biotechnology in contributing to major advances in medicine and human health.

2: Protein Conformation, Enzyme Activity

Centered around sickle cell disease, students will study the intra and inter-molecular bonding that causes proteins to take their secondary and tertiary shapes, and describe the consequences of DNA mutation on protein shape and function. While continuing to practice proper lab techniques, demonstrate accurate record keeping, and perform experimental design, students will relate their knowledge of bonding to the specific role of enzymes in biological systems by devising their own inquiry lab to study the effects of pH and temperature on catalytic activity. Students will be able to describe the chemical effects of pH, temperature, and substrate concentration on enzyme-substrate interaction, protein shape, and functionality in a formal lab report.

3: Everyday Chemicals and Human Health

By analyzing the chemical properties of a substance and their interaction with proteins and enzymes, students will examine how a chosen everyday food or product contributes to human disease. Students will research two comparable substances that were designed to serve the same purpose, and that people are or have been exposed to on a daily basis. One substance will have a historical use and be subsequently deemed unhealthy or unsafe, and the second substance will be the one that replaced it and why. Students will determine and compare the molecular structure of the target ingredient in

each product and discuss substrate concentration, solubility, oxidation state as mechanisms of poisoning where relevant, and discuss the chemical's interaction and interference with protein or enzymatic activity, and type of enzyme inhibition as appropriate. Students will prepare a Materials Safety Data Sheet (MSDS) to present their findings depicting and comparing the molecular structure of each substance, explaining the mechanism by which these chemicals interact with biological systems to cause damage to human health, and why the replacement product is safer for human use or consumption. Students will include a reflection about prevention and relevance to their personal lives. Students will choose from a given list of either environmental or food substances which may include:

- pressure treated wood (arsenic)
- red pigment cadmium in toys and jewelry
- mercury and alcohol thermometers
- margarine and butter
- artificial sweeteners and cane sugar
- hydrogenated and whole fruit, nut or seed oils
- lead and steel pipes
- flame retardants (bromine and chlorine)
- dioxines
- DEET and Citronella/Eucalyptus insect repellents
- (phthalates) plastic water bottles
- high fructose corn syrup vs. cane/beet/"natural" sugar
- teflon and cast iron

4: Microbes as Model Organisms for Human Health and Safety

In order to evaluate the efficacy of using microbes as model organisms to study human health and disease, students will test their substances from Assignment 3 in microbial assays. Students design and perform a laboratory experiment to compare the effects of their two substances on microbial growth and health. By comparing their own experimental results to published studies of known negative health impacts, students will analyze the benefits and disadvantages of using microbes as model organisms to study human health and safety. In a mini-poster session format, students will present their experimental findings and address the moral, ethical, practical, legal, cultural, and efficacy components of using microbes as model organisms.

5: Testing Plant Substances as Potential Medicines

To understand the process of researching and developing a biotechnology product, students will employ methods used to develop natural products into medicines while practicing safe specimen collection and handling, as well as proper sample labeling and preparation for testing. Students, while adopting the persona of a lab technician or research and development scientist, will gather plants from their local community to determine the degree to which these plant materials contain active ingredients that will inhibit the growth of various microbial strains (yeast, bacteria, or viruses). Students will prepare agar dishes, prepare plant extracts in various hydrophilic and hydrophobic solvents from collected samples, design and carry out the antimicrobial plant extract

assay. Based on their lab results, students will perform thin layer chromatography with various hydrophilic and hydrophobic solvents on the extracts that display microbial inhibition to isolate the chemical compounds responsible. Students will then perform the assay with the isolated chemical compounds. Students will evaluate the performance of each extract as a source of potential antimicrobial medicine, and provide evidence for their evaluations. Students will discuss possible sources of false data, and submit a written recommendation of plant extracts for further study as possible candidates as antimicrobial agents to a panel of industry experts.

Unit 4 - Waste

Driving Question: How can we use biotechnology and chemistry to manage our waste?

This unit allows students to apply Biotechnology and Chemistry concepts and laboratory skills to develop solutions to waste management problems. At this point in the course, students will have explored the role of chemistry and biotechnology in ensuring a supply of clean water, healthy food and good health and will now turn their attention to waste, a product of all those processes that can also negatively impact these processes. In this unit student groups will act as waste management consultants who have received a request to provide services to a waste management company that needs to develop solutions for a waste management problem.

To understand the waste management problem, students will – through materials gathered and/or personal interviews -- research the nature of the waste management issue, solutions that have been tried, and outcomes of those solutions. To understand the chemical and biological composition of the waste associated with the problem, students will conduct research on the waste material to determine the properties of elements, molecules, bonds and intermolecular forces in the substance. They will apply and extend their knowledge of chemical reactions and equilibrium of chemical reactions they gained in units 1,2 and 3 as they develop chemical processes to break down the waste. They will use their knowledge of enzymes, enzyme kinetics and properties of enzymes they gained in the previous units as they develop biotechnological processes to break down the waste. By testing their proposed processes in the lab through experimentation, students will learn about the factors that affect microbial growth and biochemical or chemical reactions including pH, nature of reactants and products, chemical equilibria and thermochemistry; the results of their research and experiments will allow them to understand why and how existing solutions need to be improved. Information gathered will be used to create a Current Status Report to summarize the problem and lay out recommended chemistry or biotechnology solutions.

Unit 4 - Assignments

1: Students will conduct a case study of a contemporary waste management problem that interests them. First the students will choose a waste management issue. Students will visit the site of the problem (a wastewater treatment plant, a dump, hazardous waste facility or a former industrial or military site, for example) and meet with professionals who

are trying to solve the problem. Students will determine the current way(s) the problem is being dealt with, the biological and chemical pitfalls of the current solution(s) (e.g. acidic runoff or toxicity of process due to negative effects on the activity of human enzymes), and areas for improvement in the solution design. They will then draft a Current Status Report, summarizing the current status of the waste management problem, the history of the problem, and the chemical or biotech challenges that have impeded optimal solutions.

2: Students will use the information in the draft of the Current Status Report in assignment #1 to brainstorm and propose recommendations for next steps or alternative solutions. Students will focus on recommendations or solutions that utilize biotechnology (bioremediation, for example) or chemistry to mitigate the impact of the problem on the environment and that can be tested in a school laboratory or at an external site in collaboration with a professional in the field. Students will then show proof of concept by designing and carrying out experiments to test the recommended solution using chemical reactions, microbes or plants. Through their experimental testing they will study chemical or enzymatic reactions to understand their properties and factors that affect the reactions, their thermochemistry and their equilibrium. The experimental design/redesign process and results of the tests will be documented in a lab notebook and used to propose a process to solve the waste management problem for the client.

3: After testing the recommended solution(s) using the scientific method and GLP in assignment #2 students will report their results in a finalized version of the Current Status Report (draft created in assignment #1) and use the results to make final recommendations. Although an optimal solution may not have been determined by the student group, the report could serve as an advisory report for the client. The report will be submitted to the professional(s) in the field that they met with at the beginning of the assignment. The final report will include evidence of all stages of the design/test process and explanations of all chemical and biotechnology principles used during the study.

Unit 5 - Heat and Energy

Driving question: How does energy relate to water, food, health and waste?

Students will gain and show an understanding of taking a Human produced waste product and produce a usable fuel. The process will highlight the human need of energy, how the energy is used, and the by-products of energy production. This understanding will be shown in the presentation of taking some kind of human waste (example: corn stalks) and turning it into a useable form of energy. The concepts of understanding should extend from Unit 4 and be expanded as part of Unit 5. Acting as energy experts, they will research and choose a well defined process that can be performed in the lab, and demonstrate the process. Students will then be given the opportunity to show a mastery of knowledge regarding a blending of one of the previous units with Unit 5. This knowledge will come in the form of showing how a specific unit of energy moves and changes. The report will include the theme of the energy flow from the sun to the cellular level and back to the universe, emphasizing humans' use of energy. Students will show an

understanding of the flow of a unit of energy, and use it as evidence during the defense of their poster presentation. Students will assess each other's presentations, justifying their assessments with evidence and careful reasoning.

Unit 5 - Assignments

1: How can we mitigate waste and produce cleaner forms of energy?

Students will choose a product in the human waste stream (example: waste vegetable oil) to produce a fuel that can be used for energy production. The waste product should be accessible without great difficulty. The fuel produced should be useful, minimally toxic and easy to store. Students will demonstrate the process of producing the fuel and determine the benefits and drawbacks of the process with regards to the the cost of collecting and processing the waste and manufactured fuel. The demonstration (example cellulose digest to biofuel) by the student shall take into account the biochemical/chemical reactions taking place and show how the equilibrium of the reaction(s) are changed by temperature, pressure, and/or an addition of reactants. Students will share the knowledge they have gained through the assignment with the class as well as demonstrate the process in the form of video that will be shared with industry experts, school administration, and parents for evaluation and feedback. The final assessment will include the demonstration video, student notebook write-up of assignment, fellow student reflections of the demonstration and industry expert assessment emphasizing impact in the "real world".

2: What is the role of humans in energy flow with regards to the food, water, health or waste.

Students will design and implement a project that follows a unit energy from its source (most likely the Sun) to its final state (most likely background heat in the universe) with an emphasis on how humans affect the flow in regards to food, water, medicine/health, or waste. Student shall choose one of the previous units (Food, Water, Health or Waste) with a biotech emphasis to integrate with energy for this assignment. Students will explore and document (in the form of a poster) the concept of energy flow (example: chemical energy from plant to animal) and changes in energy states (example: from potential to kinetic). Students will submit a project proposal for teacher review to ensure understanding of the project and non overlap with other students. Students will submit project updates for teacher review to ensure movement to completion of project. As part of the update process a "story board" or a flow chart of the presentation will be required. The unit of energy trip should show changes (from electromagnetic to chemical as an example) and losses in energy with mathematical explanations of each change and loss. The presentation from the students will be done in a public setting with a poster session (like one at a scientific meeting) for all science students, school administration, subject experts, parents, and community members. The final assessment will include the poster "defense", student notebook write-up of the assignment showing all calculations, industry expert assessment, and fellow student reflections of the poster.

Texts:

Water testing kits and pH meters or strips
General Chem lab chemicals and glassware
GMO PCR kit
Indicator solutions for macromolecules
General microbiology reagents
General High School Chemistry text
Ellyn Daugherty Biotechnology lab manual