

BIOTECHNOLOGY/BIOMEDICAL SKILL STANDARDS PROJECT

PHASE II ACTIVITY SUMMARY: CURRICULUM DEVELOPMENT ASSESSMENT AND ARTICULATION GUIDELINES

BACKGROUND INFORMATION

The Biotechnology/Biomedical Skill Standards Project's goal is to prepare people for employment in the Biotechnology/Biomedical field by aligning industry skill standards and educational program learning outcomes, and by articulating educational skill standards between educational institutions in the Puget Sound Region. The supporting consortium is comprised of local-area schools and colleges, organized labor and industry and includes Lake Washington School District (Juanita High School), Seattle Central Community College, Seattle Pacific University, Shoreline Community College, Shoreline School District (Shorewood High School), Tech Prep, and Washington Biotechnology/Biomedical Association (WBBA).

Phase I of the project developed and validated a set of industry skill standards organized around the following job clusters:

- Research, Development and Manufacturing
- Regulatory Affairs and Clinical Trials

PHASE II PROJECT GOALS

The primary goal of phase II was to leverage the industry skill standards information to review and strengthen existing Biotechnology programs, and to support skill articulation between high schools, 2-year colleges, and 4-year universities.

The primary goals were to:

- Review existing Biotechnology programs at two-year and four year institutions to better align with the industry Biotechnology and Biomedical Skill Standards information
- Leverage the industry Biotechnology and Biomedical Skill Standards information to support articulation between high schools, two-year and four-year colleges

COMMITTEE MEMBERS AND GUIDELINES BIOTECHNOLOGY/BIOMEDICAL SKILLS STANDARDS PROJECT

<i>GUIDELINES</i>	<i>AUTHOR</i>
<i>Material Handling & Safety</i>	Connie Kelly-Instructor, Shorewood High School
<i>Tools of Communication</i>	Mary Glodowski-Instructor, Juanita High School
<i>Career Exploration</i>	Mary Glodowski-Instructor, Juanita High School
<i>Bioethics</i>	Mary Glodowski-Instructor, Juanita High School Tracy Stoops-Instructor, Shorewood High School
<i>Exploratory Skills</i>	Tracy Stoops, Instructor, Shorewood High School
<i>Laboratory Skills</i>	Tracy Stoops-Instructor, Shorewood High School
<i>Application of Mathematics Skills to Laboratory Situations</i>	Josephine Pino, Professor, Shoreline Community College
<i>Tools of Organization</i>	Danielle Tilley, Ph.D., Professor, Seattle Central Community College
<i>Experimental Setup, Implementation, Troubleshooting, Monitoring & Analysis</i>	Caralee Cheney, Ph.D., Professor, Shoreline Community College
<i>Locating and Using Reference Resources</i>	Rick Ridgway, Ph.D., Professor, Seattle Pacific University

MATERIAL HANDLING AND SAFETY

USING CHEMICALS SAFELY

Workplace Application Biotechnology labs use a variety of organic and inorganic chemicals, several of which are not used in other types of labs. For their own safety, as well as for the safety of co-workers, biotechnology professionals must be aware of procedures for using and disposing of chemicals in an appropriate manner.

Skills Students are knowledgeable of chemical hazards in the lab and follow rules for the safe use and disposal of chemicals.

Demonstration of Skills

- Demonstrate the proper use of acids and bases
- Use waste disposal containers when required
- Clean up chemical spills following classroom rules
- Use the fume hood when required
- Are able to interpret Material Science Data Sheets and know their location

WORKING WITH MICROORGANISMS

Workplace Application Microorganisms are used in many biotechnology labs. Even when known pathogens are not in use, microorganisms are treated as potential pathogens and precautions must be taken to prevent their contact with workers as well as their spread in the laboratory.

Skills Students use proper precautions and disposal methods when working with microorganisms.

Demonstration of Skills

- Disinfect work surfaces before and after the use of microorganisms
- Handle cultures in a safe manner following classroom rules
- Dispose of cultures in designated receptacles for autoclaving
- Be able to explain universal precautions for handling blood or saliva

USING SAFETY EQUIPMENT AND OBSERVING SAFETY RULES

Workplace Application Following federal regulations, laboratories are equipped with protective and emergency equipment. Laboratory workers are responsible for their own safety as well as that of other workers. The responsible use of safety equipment and observance of safety rules is crucial to a productive work environment.

Skills Students use protective equipment, can operate emergency equipment, and can identify conditions presenting a threat to health and safety.

Demonstration of Skills

- Use personal protective equipment such as gloves and goggles in an appropriate manner
- Use general safety equipment such as the fume hood when appropriate
- Know the location and proper use of emergency equipment such as the eyewash, chemical shower, and fire extinguisher
- Follow classroom safety rules and specific precautions for laboratory protocols
- Can identify unsafe procedures in the work of others and take corrective action.

USING LABORATORY EQUIPMENT SAFELY

Workplace Application

The use of laboratory equipment in itself can pose electrical and explosive hazards. The proper use of this equipment can prevent expensive and dangerous lab accidents.

Skills

Students can use laboratory equipment safely.

Demonstration of Skills

- Demonstrate safe use of the centrifuge, gel apparatus, power supplies, microwave and autoclave
- Read and interpret technical manuals for operating equipment
- Visually inspect equipment before and after use
- Be aware of the electrical hazards associated with using different type of laboratory equipment
- Attend to equipment while it is in use.
- Demonstrate precautions necessary when working with open flames
- Be familiar with disposal methods for different types of hazardous materials.

TOOLS OF COMMUNICATION

MAINTAINING A LAB NOTEBOOK

Workplace Application

The lab notebook is an invaluable record of experimental design and results. Accuracy, timeliness, legibility, organization, and thoroughness are hallmarks of a well maintained notebook. Lab notebooks can also serve as legal documentation of the protocols and chronology of patentable product development. Because of the possible legal and monetary implications, lab notebooks are often peer reviewed in industry to ensure that all work within a project is being properly documented. Information kept in lab notebooks can also provide documentation needed for ongoing funding and grant renewals.

Skills

Students will use a set of industry standards to accurately document their lab experiences in lab notebooks. Students will also critically evaluate the notebooks of their peers for adherence to those standards.

Demonstration of Skills

- properly maintains an organized record of all lab experiences, including protocol, data, and interpretation
- notebook is consistently updated in a timely manner
- records are kept in indelible ink
- Table of Contents accurately reflects the location of all entries
- peer critiques, identifying work that follows standards
- peer critiques, upon identifying work that does not follow standards, makes appropriate recommendations to rectify shortcomings

WRITING A FORMAL LAB REPORT

Workplace Application

Most scientific developments in academia and industry are shared via the written word. Scientific journals have similar format requirements for the submission of manuscripts describing new understandings in science. Because writing is used as the major method of communication, it is essential that one is able to express new findings and their implications in a clear and concise manner.

Skills

Students will use their laboratory experiences to create a formal report using the submission guidelines of a major scientific journal.

Demonstration of Skills

Demonstrates high ability in Procedural Writing in the following areas:

- Ideas and Content
- Organization
- Voice
- Word Choice
- Sentence Fluency
- Conventions
- Presentation

Prepares a formal report which includes the following:

- Title – accurately depicts content of report
- Abstract – a single paragraph which summarizes the purpose, results, and conclusion of the experiment
- Purpose – explains the reasons for the experiment
- Background – contains pertinent information that supports experimental intent
- Methods – describes the protocols and materials used with enough detail that the experiment can be replicated by others
- Results –organizes data into graphs, tables, and charts when appropriate, describes what has occurred as a result of experimentation
- Conclusion/Discussion – analysis of results and their application
- Acknowledgments – lists all who have assisted and their contribution
- References – a bibliography of resources

ORAL PRESENTATION OF SCIENTIFIC DATA

Workplace Application

Oral communication is a key component of biotechnology professionals working together in teams. They must be able to share ideas, findings, and project updates with colleagues in settings that range from informal to formal. Formal presentations at conferences and symposia are methods of introducing significant developments to the scientific community. Clear oral communication is critical in the workplace when teams are teaching/learning new protocols and in dealing with incorporating new equipment into the lab. Besides sharing information from their own projects, it is common for researchers to also share pertinent and interesting information from published articles in a “journal club” setting.

Skills

Students will orally present information from their own scientific data from their experimental findings, as well as scientific data from published sources. Students will also present oral instructions to peers on how to perform a new protocol or use a new piece of scientific equipment.

Demonstration of Skills

Presentation of Student's Own Scientific Data

- presents information at an appropriate level for the listening audience
- summarizes intent, experimental design, results, and conclusions
- supports conclusions with quantitative evidence
- interacts appropriately with audience through discussion and questions and answers
- appropriately use visual aids and technology
- credits resources used

Presentation of Published Scientific Data

- presents information at an appropriate level for the listening audience
- identifies the interest and/or appropriateness of the article to conclusions

- correctly identifies analytic, quantitative, and scientific information found in the text
- accurately discusses the content of the text
- reflects on his/her own opinion of the text
- expression opinions about quantitative or scientific conclusions in the text

Explain to peers how to perform a protocol or use a piece of equipment

- explains the purpose of the protocol or equipment
- demonstrates proper use and explains what the expected results should be
- cites references and location of written instruction within the lab
- assists peers in using the protocol or equipment
- serves as a peer reference in subsequent use of the protocol or equipment

USING DATA BASES

Workplace Application

The advent of genomic studies has presented researchers with massive amounts of information to interpret. One of the most effective ways to make sense of large amounts of raw data is to organize these findings into data bases that allow interpretation to take place based on patterns, similarities, and differences. Bioinformatics is one of the fastest growing disciplines associated with biotechnology. It allows for the communication of large amounts of information to be organized in a manageable and relevant way. Being able to access and utilize these data bases is critical to the advancement in understanding of nearly every aspect of biotechnology research.

Skills

Students will be able to access and utilize information in data bases to support their investigational research.

Demonstration of Skills

- describes the variety of information stored in data bases applicable to biotechnology
- accesses genomic data bases to compare similarities of a specified gene in several organisms
- accesses genomic or proteomic data bases to compare similarities of selected organisms
- accesses other biological data bases for reference as needed in research or presentations – could include data bases on cell lines, restriction enzymes, plasmids, or human genetic disorders, as examples

CREATING AND INTERPRETING GRAPHS, CHARTS, AND TABLES

Workplace Application

One method of organizing experimental results for interpretation is to incorporate data into a graph, chart, or table. Large amounts of what may seem to be unrelated pieces of information can show important trends when appropriately organized. It is essential that biotechnology professionals are skilled in the methodologies needed to convert their results into easily accessible graphics for interpretation by others. In addition to creating these graphics, it is imperative that one is able to interpret the graphics of others.

Skills

Students will create graphics to organize experimental data. Students will also correctly interpret the information presented in graphics.

Demonstration of Skills

Creating Graphs, Charts, and Tables:

- creates a spreadsheet
- creates and edits data tables
- creates and modifies simple forms and reports
- imports and exports database information to and from other applications
- uses appropriate techniques to create a graphic and appropriately plots data
- titles and fully labels all aspects of a graphic
- identifies dependent and independent variables and places them on appropriate axes for graphing
- chooses the appropriate type of graphic for displaying data – histogram, line graph, pie chart, scatter diagram

Interpreting Graphs, Charts, and Tables

- assesses the content of the graphic
- accurately identifies the message and purpose of the graph, chart, or table
- recognizes and describes the cause/effect relationship of the variables

CAREER EXPLORATIONS

CAREER EXPLORATIONS IN BIOTECHNOLOGY

Workplace Application

Biotechnology industries employ personnel with a variety of educational backgrounds that may range from Associate Degrees to Ph.D. The organization of a company and of individual labs may rely upon the interaction of employees with widely varied specialties. Continuing education is a key component in any rapidly changing field, and can often lead to new job opportunities.

Skills

Students will be able to access information about careers in biotechnology and locate and respond to appropriate job listings.

Demonstration of Skills

- prepare an effective resume and cover letter
- prepare an electronic resume
- participate in a mock job interview
- identify possible career paths and determine the steps needed for advancement
- identify major biotechnology centers throughout the world
- describe the history of the biotech industry in the local community
- access company web sites for information on focus, products, services, and range of job opportunities
- use industry web sites and classified ads to access information on career opportunities and identify jobs for which they are adequately prepared

BIOETHICS

BIOETHICS IN THE BIOTECHNOLOGY WORKPLACE

Workplace Application

Decision making is a daily component of the work of biotechnology. Some of the decisions that need to be made are bioethical in nature. Biotechnology professionals must be able to make decisions that protect the integrity of their research and of those who are affected by their work. Experimental results need to be reported completely and honestly, even when they may not favor the expected outcome. Access to information may be ethically limited in clinical settings to protect the privacy rights of patients, and it may be limited in research settings to protect proprietary information. Regulatory agencies are responsible for formulating the standards to be followed in situations that include clinical trials on human subjects, animal research, and the safe disposal of hazardous products. Every biotechnology professional is ethically, if not legally, required to uphold those standards.

Skills

Students will work ethically in all academic, lab, and career situations.

Demonstration of Skills

- consistently report data with honesty
- explain how sensitive clinical or research information is appropriately disseminated
- identify the possible consequences of unethical behavior
- define and identify the components of an ethical dilemma
- identify and apply bioethical principles and values to case studies using references and models such as the Belmont Report, the Hastings Model, and the Ball State Model
- use a decision making model to analyze an ethical dilemma
- access information on regulatory agencies for information on protocols for clinical trials of human subjects and for animal research such as the FDA and IACUC

EXPLORATORY SKILLS

QUESTIONING, CRITICAL THINKING AND PROBLEM SOLVING SKILLS

Workplace Application

Science is a field in which life long learning and discovery is essential for progress. In the work place, biotechnology professionals must be able to think critically, ask questions and research information in order to improve their ability to work and learn.

Skills

Students will master the following skills:

- Identify a problem during an experimental procedure and the cause of the problem.
- Know where to find and research accurate protocols, procedures and background information.
- Detect and identify erroneous results.
- Calculate and minimize errors.
- Develop and expand ideas and insights
- Estimate or predict a result and compare to actual data.
- Make accurate observations and note when events are discrepant.
- Document errors in order to prevent repeating errors.
- Identify patterns and extrapolate meaning.

Demonstration of Skills

- Ability to write protocols that expand experimental procedures
- Research and compare similar procedures and discern the most appropriate for the task.
- Find the source of error in a given experiment and determine the necessary corrections.
- Reflect on an experiment and determine the steps that could be taken in order to maximize results.
- Develop a list of reliable sources for procedures, protocols and background information.
- Analyze data and identify discrepant or erroneous results.
- Analyze data and identify any observable patterns and their meaning.
- Accurately document observations, errors and problems in a procedure.
- Test a solution to a problem in a safe environment before implementing on a whole system.

LABORATORY SKILLS

SKILLS: PROTOCOLS, PROCEDURES AND STANDARDS

Workplace Application

The ability to follow specific laboratory protocols using the correct procedures while incorporating appropriate standards and controls is an essential part of all laboratory testing. Whether a student will be seeking employment in a clinical laboratory, a research laboratory, a production plant, or be involved in quality control this skill must be utilized and is, therefore, one of the most important components involved in training biotechnology students for the work place.

Skills

Students will master the following skills:

- Read protocols, test procedures or standard operating procedures.
- Identify controls, standards, independent variables and dependent variables in the various procedures.
- Properly prepare all samples and reagents for testing.
- Be familiar with equipment and be able to determine if equipment is functioning properly.
- Be able to perform the required test or assay.
- Use appropriate controls and standards.
- Return, archive or dispose appropriately of all samples and reagents involved.

Demonstration of Skills

- Students read and successfully follow a protocol with no needed instructional assistance.
- Students are familiar with and/or can perform the following procedures:
 - Electrophoresis
 - Chromosomal DNA and Plasmid Isolation
 - Restriction Digest and Analysis
 - Bacterial Transformation
 - Protein Purification
 - Polymerase Chain Reaction
 - Western Blotting
 - ELISA
 - Plasmid Mapping
 - DNA Sequencing and Analysis
- The required test or assay is completed according to the protocol and procedure.
- Safety protocols and procedures are used at all times.
- Student follows and uses appropriate protocols for sterile technique.
- All samples and reagents are made to the required specifications in the protocol.
- Equipment is operated safely and accurately for each test attempted.
- All controls and standards are used appropriately and are within range.
- The lab bench is left clean and safe and all samples and reagents have been removed as appropriate.

APPLICATION OF MATHEMATICS SKILLS TO LABORATORY SITUATIONS

MAKING AND REPORTING LABORATORY MEASUREMENTS

Workplace Application

Accurate measurements of volume, length, temperature, and mass are crucial to a variety of laboratory activities, including (but not limited to) solution preparation, solution dilution, and instrumentation usage. The measurements must be made and reported with the optimal degree of precision and accuracy which is consistent with the available measuring instruments. The universal convention in science is for measurements to be made and reported using metric system units. Values are expressed using scientific notation for consistency as well as to allow accurate and convenient calculation without the use of a calculator.

Skills

Students will accurately perform and report measurements of volume, length, temperature, and mass.

Demonstration of Skills

- Create a table which defines the metric system prefixes (nano as the lowest and kilo as the highest) in numerical form as powers of 10.
- Express any number in scientific notation.
- Perform metric system unit conversions without a calculator, using scientific notation.
- Perform calculations using scientific notation with the appropriate number of significant figures.
- Given a graduated cylinder containing liquid, a thermometer, or an object of a certain length or mass, report the metric measurement using scientific notation with the proper number of significant figures.
- Demonstrate the use of micropipettors, graduated cylinders, volumetric flasks, and glass pipets for measuring and transferring liquid.
- Select the proper instrument (appropriate pipet or glassware) for measuring a desired volume of liquid.
- Accurately measure and transfer a desired volume of liquid; be able to do this with volumes ranging from 0.5 microliter to 1 liter.
- Accurately measure and transfer a desired mass of a solid; be able to do this with masses ranging from 10 mg to 1kg.

CALCULATIONS FOR THE PREPARATION AND DILUTION OF CHEMICAL SOLUTIONS

Workplace Application

Chemical solutions are used in virtually every experiment and procedure in the laboratory. The solution concentration must be accurately calculated and prepared for optimal results. For various reasons, concentrated stock solutions are often made and stored.

These stock solutions must be diluted accurately and consistently prior to use.

Skills Students will apply principles of chemistry and mathematics to prepare recipes and actual solutions.

*Demonstration
of Skills*

- Explain the concept of “percentage” and, given any two numbers, calculate the percentage of one relative to the other.
- Perform basic algebraic calculations using numbers which express the units of measurement (length, mass, volume, and temperature).
- List the various ways of expressing the concentration of solutions including molarity, g/ml, and percentages.
- Perform conversions between concentration units. (eg. g/ml to mg/L)
- Given the percent concentration of a desired chemical solution, calculate the correct amount (mass or volume) of the components to be mixed together.
- Given the molarity of a desired chemical solution, calculate the correct mass of the solute and volume of solvent to be mixed together.
- Given the concentrations of a stock solution and a desired final solution, perform the calculation to accurately perform the dilution. For example, dilute a 100X (“100 times concentrated”) solution to 1X.
- Given a desired solute concentration, prepare a solution in the laboratory.
- Perform a solution dilution in the laboratory.
- Starting with a basic (one solute) solution recipe, perform the necessary calculation to change the recipe to accommodate a larger desired volume. (For example, a recipe for 1 Liter of solution would be changed to be able to produce 2.5 Liters of the same solution.)
- Demonstrate the proper labeling and dating of a prepared solution.

**USING THE
CONCEPT OF pH**

*Workplace
Application*

Solutions that are used in biological experiments and procedures must be of the appropriate acidity or alkalinity in order for the other solution reagents such as enzymes to function correctly. Accurate solution preparation often requires that the technician determines the correct volume of acid or base to be added to modify or create the appropriate pH. In addition, the final pH must be measured and reported.

Skills Students will demonstrate an understanding of the numerical and chemical concept of pH and will be able to determine whether a given solution requires acid or base addition to achieve a desired pH.

*Demonstration of
Skills*

- Given the hydrogen ion concentration of a solution, calculate the pH.
- Given the pH of a solution, calculate the hydrogen ion concentration.

PERFORMING AND USING GRAPHICAL REPRESENTATIONS OF LABORATORY DATA

- Explain the numerical relationship between two different pH values.
- Given a solution pH, be able to explain whether acid or base should be added to achieve a desired pH

Workplace Application

Experimental data is often reported in graphical format, both in routine laboratory procedural reports as well as scientific or company publications. In addition, standard curves are prepared and used for the determination of quantities such as protein concentration and enzyme activity.

Skills

Students will graph a set of data for use as a standard curve.

Demonstration of Skills

- Given a set of data, be able to identify the dependent and independent variables and place the values on the appropriate axes.
- Graph data to create a standard curve using standard graphing paper and use the resulting standard curve to determine the value of an unknown sample.
- Graph data to create a standard curve using semi-logarithmic graph paper and use the resulting standard curve to determine the value of an unknown sample.

TOOLS OF ORGANIZATION

LABORATORY PREPARATIONS

Workplace Application

The successful researcher will have prepared and planned for experiments before entering the lab facility. By planning ahead the student will be aware of the necessary equipment, supplies and expected outcome of the experimental design.

Skills

Dissemination of objectives, experimental design and expected results from assigned reading.

Demonstration of Skills

- Complete pre-lab exercise or quiz-to-include: title, purpose, objectives and possible outcomes.
- Generate a complete list of supplies and required equipment.
- Prepare a flow chart which accurately reflects the critical experimental components, experimental steps and the order in which they are to be executed.

EFFICIENT USE OF LABORATORY TIME

Workplace Application

The successful technician will be able to execute several procedures simultaneously. This expectation will be directly related to the technician's ability to organize time and resources. This time management includes proper documentation of the procedures executed the same day.

Skills

Student will learn to maximize down time in the experimental procedures. Down time is defined as a lapse in hands-on manipulations. These times are usually in the form of an incubation step or necessary time to complete a procedure such as electrophoresis or gravity flow through a column, to name some examples.

Demonstration of Skills

- Complete a flow chart that reflects the time requirements for all planned procedures. The flow chart should reflect time lapses in the main protocol and include alternative and time appropriate procedures which can be initiated during that down time
- Use down time to complete documentation of the experiment in an industry style notebook. The documentation should be done in parallel with the procedure, not after the fact.
- Examples: while an agarose gel electrophoresis is proceeding the technician could begin a restriction digestion or enter data into their notebook as opposed to waiting until the electrophoresis is completed.
- Submit notebooks for review by the instructor.

WRITTEN DOCUMENTATION

Workplace Application

The laboratory notebook is the final account of the protocols and procedures utilized by the researcher or technician. It is critical to the company or facility that the book be accurate and current. These records will be used to refine experiments, apply for patents,

apply for funding and verify results for future applications. A notebook that is incomplete or illegible is of no value to the employer.

Skills Students will maintain an industry style notebook

Demonstration of Skills

- The lab notebook will only reflect laboratory exercise - lecture notes will be kept separate.
- The notebook is not a loose leaf binder but a bound book.
- All entries will be in indelible ink.
- There will be an updated table of contents
- The signatures should be filled in and completed at the time of the experiment.
- There is to be no white out or eraser marks.
- There will be no pages taped over the originals.
- There should be complete sections with a title, purpose, materials, procedures, flow chart, results and conclusions.
- All lot numbers and batch numbers should be recorded for future reference.
- All equipment utilized should be recorded.

EXPERIMENTAL SETUP, IMPLEMENTATION, TROUBLESHOOTING, MONITORING AND ANALYSIS

DESIGN OF CONTROLLED EXPERIMENTS

Workplace Application

A key focus in a biotechnology laboratory is scientific inquiry. All scientific inquiry requires the use of the scientific method. Therefore, those who work in the area of research or applied science must have a firm understanding of the scientific method. They must know how it is applied and how the results may be interpreted. This understanding will allow the lab worker to design valid controlled experiments to be used to address a particular question or problem.

Skills

- Understanding of and ability to appropriately apply the scientific method to a particular question.
- Demonstrate consistent use of well-developed critical thinking skills.
- Understanding of available methods, materials and equipment and ability to use this knowledge to design an experiment that accurately tests the hypothesis which has been developed.
- Understanding of the use of controls and ability to design appropriate controls.

Demonstration of Skills

- Given a question to be addressed, apply the scientific method.
- Development of a hypothesis to address the question at hand.
- Design an experiment to test the hypothesis. This will include selection of appropriate equipment, supplies and materials.
- Establish appropriate controls.
- Establish methods for appropriate data collection and analysis.
- Students defend whether the experiment truly isolates the variable to be tested and whether the results support the hypothesis.
- Students identify the controls, determine whether they are adequate/appropriate and suggest what problems may occur which effect the validity of the data.
- Students identify what other experiments might be undertaken which would also test the hypothesis.

The above demonstration of skills can be done as a theoretical exercise or the experiment can actually be conducted.

- Read an appropriate scientific paper and identify the hypothesis, the controls, the validity of the data collection and analysis, determine whether the experiment is properly designed and why.
- Students identify questions, develop several possible hypotheses and several possible experiments to test those hypotheses.

IMPLEMENTING AND TROUBLESHOOTING EXPERIMENTAL PROTOCOLS

Workplace Application

It is necessary to be able to carry out protocols as they are presented. It is also necessary to have adequate understanding of the methods, materials and equipment to recognize whether the experiment is proceeding appropriately and to effectively troubleshoot as necessary.

Skills

- Ability to follow a protocol.
- Comprehension of a technical vocabulary.
- Use of correct labeling procedures.
- Competent use of needed equipment, recognition of equipment malfunction.
- Recognition of proper appearance of supplies and materials; note expiration dates.
- Complete and check calculations as appropriate.
- Careful attention to detail in planning, execution and follow-up.
- Recognition of problems and the ability to address their resolution in an orderly fashion. Seek assistance as necessary.

Demonstration of Skills

- Given an assigned protocol, develop a written outline/plan to be used to conduct the experiment. The outline/plan should have sufficient detail to be used to conduct the experiment. This will allow student to carefully think through the necessary steps. This can include calculations and/or actual preparation of solutions/media, calibration of the equipment or other steps the instructor wishes to add.
- Be able to identify the role and appropriate use of all the components of the protocol. This will include all chemicals, biological components and equipment.
- Carry out an assigned protocol.
- Monitor progress of experiment and identify problems or irregularities as they occur. Suggest/implement solutions as appropriate.
- Know and use appropriate lab procedures and safety precautions.

MONITORING, DATA COLLECTION AND ANALYSIS

Workplace Application

Experimental data must be collected in an appropriate form. Standards and controls must be used. Data must be interpreted for validity and to determine experimental outcome. Workers must be able to communicate these results to others.

Skills

- Collect and record data in a consistent manner and with careful attention to detail.
- Accurate and appropriate documentation of results, data collection and interpretation of those results.

Demonstrations of Skills

- Statistical analysis of data as appropriate.
- Ability to report results to others in an efficient, meaningful manner.
- Suggest modifications to experimental design as a result of troubleshooting efforts and data analysis.

- Determine whether the data is a valid test of the hypothesis. This will include comparison to controls and standards as well as statistical analysis.
- Identify experimental irregularities which may have affected the data.
- Develop a new hypothesis which may be suggested by the experimental data.
- Work with example data sets to practice analysis. Include unexpected results and students suggest possible causes.

The above scenarios may be assigned to individuals, lab partners or groups.

LOCATING AND USING REFERENCE RESOURCES

USING THE SCIENTIFIC LITERATURE

Workplace Application

Advances in science, including those in biotechnology, typically build on what is already known; that is, they emerge from the efforts of scientific workers, both past and present. The most permanent records of such efforts are the scholarly publications of these workers that are available to anyone primarily through research library collections and online search mechanisms. To understand the relevance of the scientific work they are involved in, as well as to communicate effectively with colleagues, biotechnology professionals need to develop competent information-literacy skills.

Skills

Students are knowledgeable regarding how to locate the scholarly work of others, how to critically evaluate such literature sources, and how to incorporate information retrieved from such sources into their own scholarly writings.

Demonstration of Skills

- Use available library resources to locate reference materials:
 - on general and specific topics relevant to biotechnology
 - on specific biotechnology protocols or procedures
 - by a specific authors (or authors)
 - on specific bioethical issues
- Use available library searching mechanisms (e.g., abstracts, index guides) and online services to locate, critically evaluate, and discriminate among reference sources of various types, for example:
 - primary scientific literature (articles in peer-reviewed journals relevant to biotechnology)
 - secondary scientific literature (review articles or books; technical reports; laboratory manuals and preparation guides; academic dissertations/theses; scientific meeting abstracts)
 - the popular literature (articles in popular journals and periodicals)
 - anonymous online publications and related web sites
- Incorporate information retrieved from reference resources appropriately and honestly by
 - taking down notes in their own words
 - providing full credit to, and accurate citations of, all sources utilized
 - avoiding any and all forms of plagiarism
 - respecting copyright and intellectual property laws

LOCATING SOURCES OF EQUIPMENT, REAGENTS, SUPPLIES, AND SAFETY INFORMATION

Workplace Application Many different kinds of equipment, reagents, and related supplies are used by workers in biotechnology. Being able to efficiently locate and contact the manufacturers and/or vendors of such materials is an important skill in biotechnology laboratories. Manufacturers and vendors are also a primary source of information on the safe use, maintenance, storage, and disposal of materials used by biotechnology workers.

Skills Students are knowledgeable regarding how to locate companies that manufacture and/or distribute the various kinds of equipment, reagents, and related supplies commonly found in biotechnology laboratories.

Demonstration of Skills

- Use available laboratory, library, or online resources to
 - locate manufacturers/distributors of specific kinds of equipment, reagents, and related supplies
 - request and obtain relevant product information, pricing catalogs, user manuals, application guides, and safety information (e.g., material safety data sheets) from manufacturers/distributors
- Use information obtained from above sources to
 - compile a list of specific equipment, reagents, and supplies needed to carry out a proposed experiment or research project
 - estimate the costs of purchasing, maintaining, storing, and safely disposing of reagents, supplies, and equipment associated with a proposed experiment or research project
 - produce a technical document on the safe use and maintenance of a specific piece of equipment or on the safe handling, storage, and disposal of specific reagents or supplies associated with a proposed experiment or research proposal

SOME REFERENCES FOR INFORMATION ON PROPER CITATION OF PRINT AND ONLINE RESOURCE MATERIALS

- CBE Style Manual Committee, Council of Biological Editors (1994). *Scientific Style and Format: The CBE Manual for Authors, Editors, and Publishers* (6th Edition). Cambridge Univ. Press, New York.
- Davis, E.B. and D. Schmidt (1995). *Using the Biological Literature* (2nd Edition). Marcel Dekker, Inc.
- Hacker, D. (1999). *Research and Documentation in the Electronic Age*. Bedford/St. Martin's, Boston, MA.

Harnack, A. and E. Kleppinger (2000). *Online! A Reference Guide to Using Internet Sources*. Bedford/St. Martin's, Boston, MA.

Hurt, C.D. (1998). *Information Sources in Science and Technology* (3rd Edition). Libraries Unlimited, Englewood, CO.

McMillan, V.E. (2001). *Writing Papers in the Biological Sciences* (3rd Edition). Bedford/St. Martin's, Boston, MA. (ISBN 0-312-2587-7)

Pechenik, J.A. (1997). *A Short Guide to Writing About Biology* (3rd Edition). Addison Wesley Longman, New York. (ISBN 0-673-52503-1)

SOME REFERENCES FOR INFORMATION ON INTELLECTUAL PROPERTY RIGHTS AND COPYRIGHT ISSUES

The Center for Advanced Research and Study on Intellectual Property (CASRIP) of the University of Washington School of Law. (<http://www.law.washington.edu/casrip>)

Harris, L.E. (1997). *Digital Property: Currency in the 21st Century*. McGraw-Hill Ryerson, New York.

Langford, J. (1997). Intellectual property rights: technology transfer and resource implications. *Am. J. Agric. Econ.* 79: 1576-1583, 1592-1594.

Persley, G.J. (1997). Global concerns and issues in biotechnology. *Hort. Sci.* 32: 977-979.

Tribble, J.L. (1995). Gene ownership versus access. In: *Genes for the Future: Discovery, Ownership, Access*. National Agricultural Biotechnology Council, Ithica, NY., pp. 97-103.