INTRODUCTION

Science Standards of Learning

Experimentation involves systematically using skills of scientific methodology, including observing, predicting, measuring, defining, controlling and manipulating variables, and interpreting, analyzing and evaluating data. That is how the information about science that eventually became the content for our textbooks was generated. Now, learning science through classroom investigation is part of the Virginia Science Standards of Learning. In accordance with the standards, students will *investigate* as well as *understand* science content. They will safely develop and use experimental design and technology in scientific inquiry, and will use the language of science to communicate understanding. *Experiment with Enzymes* provides a framework to teach and learn science through experimentation.

Students will INVESTIGATE and UNDERSTAND.

The experimental pathway

Experiment with Enzymes begins with student explorations of a floating disc assay system that is used to monitor the effect of yeast catalase on the rate of decomposition of hydrogen peroxide. Then, based on observations made during the student explorations, the teacher guides the formulation of a research question and hypothesis and the development of an experimental design and detailed procedure for a class investigation of the effects of varying hydrogen peroxide concentration on the rate of the reaction. The experimental design includes identification of independent, dependent and uncontrolled variables, and specification of controls and numbers of replicates for the class experiment. The procedural plan includes calculating a dilution series and setting up a table for making the dilutions. Following student data collection and pooling of class data on a spreadsheet, the teacher guides an analysis and discussion of the class data. Statistical analysis of the data includes calculating and discussing the significance of range, mean, variance and standard deviation. Graphical analysis includes making a scatter plot, fitting a curve through the data points and plotting means with error bars. Student teams then use this experimental model to design and carry out their own investigations of varying temperature or pH on the rate of the reaction. Students are provided with the opportunity to apply increasingly sophisticated technology to data collection, analysis, and communication of results. They are also taught to use the Internet to access scientific databases and literature. Students who have been guided along this pathway by their teacher now have the experience and skills they need to pursue their own independent experimental pathways.

This manual provides the information that will enable the teacher to act as a guide for students along the experimental pathway.

INTRODUCTION

The focus on enzymes

Enzymes are substances that make life possible. We are able to live only because we have in our cells thousands of different kinds of enzymes that regulate our life processes, including: building new tissue, replacing old tissue, converting food to energy, disposing of waste materials, fighting invaders and reproduction. Enzymes are needed for every chemical reaction that takes place in all living cells; without enzymes, these reactions would take place far too slowly to maintain life. ***Experiment with Enzymes*** focuses on the enzyme catalase. Enzymes called catalases or peroxidases catalyze the decomposition of hydrogen peroxide into molecular oxygen and water. They are produced by organisms from each Kingdom. The classical introductory biology "lab" demonstrates the action of catalase enzymes. Pieces of fresh liver and potato are put into solutions of hydrogen peroxide. The fizzing occurs as the peroxide decomposes and oxygen gas is produced. Some bacteria produce catalase and can be identified by fizzing when peroxide is placed on the bacterial colonies growing on agar. ***Experiment with Enzymes*** uses Baker's yeast, *Saccharomyces cerevisiae*, as the source of catalase. A drop of yeast suspension in a solution of hydrogen peroxide produces the familiar fizzing that indicates decomposition.

Students will investigate and understand BIOCHEMICAL PRINCIPLES essential for life, including the nature of enzymes.

Students will investigate and understand LIFE FUNCTIONS of monerans, protists, fungi, plants and animals, including a comparison of their metabolic activities.

Materials are readily available. Tools are simple and can be reused.

The experiments in ***Experiment with Enzymes*** do not require specialized or sophisticated equipment. The only essential supplies are plastic: small cups or portion cups, transfer pipettes and 24-well microwell plates. These can be reused. Consumable materials are readily and inexpensively available: hydrogen peroxide (3% solution) from the drugstore or supermarket is used as the substrate, and yeast from the grocery store produces the enzyme. The yeast can be used right out of the package; cultures do no need to be maintained. These materials can be handled safely and disposed of right down the drain. Very small quantities are used and results are evident in seconds and minutes. So, each student can have the opportunity to handle materials. Each student can try things over and over again, can make mistakes, pour them down the sink and try again. This means that work can be refined and repeated several times even during a 45-minute class period. Students can even work with the materials at home.

There are no prerequisites

There are no specialized laboratory skills required to begin experimentation. Students must be able to use droppers and count drops, and time by counting seconds. No technical expertise is needed so the focus can be on developing experimental attitudes: encourage your students to ask and attempt to answer their own questions by working with the materials.

INTRODUCTION

Scheduling

Modeling an experimental pathway: The teacher leads students sequentially through an experimental pathway that can serve as a model for subsequent, more independent student explorations. Students learn basic skills of observation, experimental design and data collection and analysis. They also have the opportunity to build laboratory skills through repetition and refinement, including: measurement, manipulation of equipment, safe laboratory conduct and appreciation of the need for standardization and a methodical approach. This will take about five ninety minute class periods, and can be conducted in parts as follows:

10 student exploration of an assay system (30 to 90 minutes)

11. teacher-led discussion of student observations and formulation of experimental research question and hypothesis (30 minutes)
12. development of a class experimental procedure (60 to 90 minutes)
13. student data collection and spreadsheet input of class data (60 to 90 minutes)
14. class data analysis by graphing, summary discussion and evaluation of the procedure (90 minutes, or with homework)

Based on this model, student teams can design and follow their own experimental pathways. Student teams explore temperature and pH effects on the system. They design experiments and write their own procedures. Additional skills can be developed as students use more sophisticated technology for data collection, analysis and/or presentation. Students can also learn to refer to popular and scientific literature and databases as they conduct the laboratory research.

Do I need to wait until my students have learned about enzymes to start this pathway?
No, students can investigate catalase activity as an introduction to cells, enzymes, metabolism or other facets of the curriculum.

Features of this laboratory manual

Strategies
- illustrated procedures and description of materials
- scripts for class discussions
- questions that encourage students to think
- suggestions for classroom laboratory management
- options for assessment

Strategies are located on odd numbered pages.

Resources
- the chemical nature of enzymes, why they behave as they do
- methods for classroom experimentation
- sample data
- anecdotal information about how students have responded
- references to sources of more information

Resources are located on even numbered pages.

Appendix.
- Information for ordering materials
- directions for students
- student sheets
- assessment rubrics