THE WRITE PATH II: An Advanced College Preparatory Reading and Writing Program for High Schools

LIFE AND PHYSICAL SCIENCE

TEACHER GUIDE

High School Level

Developed by:
Leslie Hays and Karen Molloy

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About the Authors

Leslie and Karen began their professional relationship at Helix Charter High School in southern California and found that their passion for science teaching and high expectations for all students produced amazing synergy. They refined their presentations for their colleagues at numerous AVID Summer Institute Trainings, and continued to use the classroom as their "living laboratory" for enhancing best practices, especially around effective methodologies. They worked together, along with Chuck Downing, to write the first *Write Path in Science* publication, which has been revised as a resource for grades 6–12. Their collaboration has continued over the years, and they were delighted to be able to team up again to author this publication, *The Write Path II: An Advanced Preparatory Reading and Writing Program for High Schools.*

Leslie Hays

Leslie Hays, Ed.D has been inspiring secondary students for twenty years. Her passion for science education and realization that a scientifically literate student required both effective pedagogy and engaging, but rigorous, content has led her on a journey of exploration. Leslie has been an active curriculum developer and has written many curriculum guides, including the first *Write Path in Science* publication. Her quest for more knowledge led to doctoral work, her dissertation is titled "AVID Program Graduates: Negotiating the First Year of College." Leslie currently works at the San Diego County Office of Education as Director for Learning Resources and Educational Technology Support.

Karen Molloy

Karen has been teaching science since 1994 including marine science, integrated science and all levels of chemistry. She loves a dynamic classroom environment and enjoys challenging her students to meet the highest of academic standards. Professionally, Karen presents at national and county-level conferences, is a staff developer and creates curriculum that guides students in using science process skills. She holds a Bachelor's of Science from The College of William and Mary, a Master's Degree in Education with a concentration in Curriculum and Instruction from San Diego State University and has achieved National Board Certification (AYA/Science). Karen currently teaches chemistry in Fairfax County Public Schools in northern Virginia where she enjoys the love and support of her husband and two daughters.

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INTRODUCTION

Introduction

Welcome to a curriculum written to increase skills of science students undertaking rigorous coursework. In this book, we introduce a variety of AVID methodologies of WIC-R (Writing, Inquiry, Collaboration, and Reading) to help students become more competent in their abilities to learn challenging content. The authors have found in their own work in many types of science classes with students who come with various degrees of readiness, that the strategies and labs presented in this publication work. We invite you to join us as we go through a series of units designed to prepare students to learn the fascinating realm of scientific discovery and exploration of the natural world.

The impetus for this second volume of the Write Path for Science has been the positive response to the first volume and requests for more rigorous strategies for science students in Pre-AP and AP courses. These activities support National Science Teaching Standards. In particular, two premises of the National Science Teaching Standards are found at the philosophical core of the materials found here.

Premise 1

What students learn is greatly influenced by how they are taught. When science is taught in a didactic manner, concerned only with right answers, students will have very different perceptions about science. This method of teaching restricts students to answering questions rather than asking them. If our students cannot learn how to ask good questions, where do we expect to find the great researchers of tomorrow? How will these students be able to do science? While there is a need to know about science, there is an ever-increasing need to be able to think about science and then apply that understanding.

Premise 2

Student understanding is actively constructed through individual and social processes. The learning process occurs over time with hard work and dedication. Many students today hold that a teacher's primary job is be filling their brains with information. Unfortunately, this does not really meet the definition of true learning because learning is the process of creating an understanding of interconnected and related concepts. Knowing isolated facts is an excellent skill for excellence on game shows and board games; in reality, though, knowing isolated facts does not win you the Nobel Prize. It takes critical thinking, synthesis and application to succeed in life as well as rigorous coursework. We also understand that learning can take place as an individual and in a group. Often times, science requires the combination of disciplines to make forward strides. How far do you think the space program would have gotten with only rocket scientists? How far do you think the medicine would have gotten with only biologists? Do you think that we could have identified the structure of DNA without the physics of x-ray crystallography?

The major theme of the National Science Teaching Standards focuses on how teachers help to prepare students to work together to discuss science in an inquiry setting. The non-discipline specific science teaching standards that are directly touched through the ideas in this publication are listed here because it is through these standards that we make a significant impact on student success in AP level courses.

Teaching Standard A

Teachers of science plan an inquiry-based science program for their students. In doing this, teachers

- select teaching and assessment strategies that support the development of student understanding and nurture a community of science learners.
- work together as colleagues within and across disciplines and grade levels.

Teaching Standard B

Teachers of science guide and facilitate learning. In doing this, teachers

- focus and support inquiries while interacting with students.
- orchestrate discourse among students about scientific ideas.
- challenge students to accept and share responsibility for their own learning.
- recognize and respond to student diversity and encourage all students to participate fully in science learning.
- encourage and model the skills of scientific inquiry, as well as the curiosity, openness to new ideas and data, and skepticism that characterize science.

Teaching Standard C

Teachers of science engage in ongoing assessment of their teaching and of student learning. In doing this, teachers

- use multiple methods and systematically gather data about student understanding and ability.
- analyze assessment data to guide teaching.
- guide students in self-assessment.
- use student data, observations of teaching, and interactions with colleagues to reflect on and improve teaching practice.

Teaching Standard D

Teachers of science design and manage learning environments that provide students with the time, space, and resources needed for learning science. In doing this, teachers

- structure the time available so that students are able to engage in extended investigations.
- create a setting for student work that is flexible and supportive of science inquiry.
- identify and use resources outside the school.
- engage students in designing the learning environment.

Teaching Standard E

Teachers of science develop communities of science learners that reflect the intellectual rigor of scientific inquiry and the attitudes and social values conducive to science learning. In doing this, teachers

- display and demand respect for the diverse ideas, skills, and experiences of all students.
- enable students to have a significant voice in decisions about the content and context of their work and require students to take responsibility for the learning of all members of the community.
- nurture collaboration among students.
- structure and facilitate ongoing formal and informal discussion based on a shared understanding of rules of scientific discourse.
- model and emphasize the skills, attitudes, and values of scientific inquiry.

As though it is not enough to teach students how to learn and succeed in rigorous classes through the Teaching Standards, it must be remembered that science teachers are also expected to teach and reinforce the science content standards. Depending on your state and district, there are also two other levels of content standards that science teachers must decipher. In most cases, the state or district level standards will take precedence (but hopefully fall within the scope of) over the National Science Content Standards as the No Child Left Behind legislation mandates assessment in science courses. There is however, an easier framework for organizing these ideas as suggested by the National Science Content Standards Unifying Principles suggests. When looking at the whole of science, there are seemingly five themes that organize the study:

1. systems, order, and organization;
2. evidence, models, and explanation;
3. change, constancy, and measurement;
4. evolution and equilibrium and
5. form and function.

These ideas are woven throughout each science course traditionally offered in high schools as well as throughout the AP Science courses. Providing students these themes as frameworks for learning will strengthen the idea that science works as a collaboration of disciplines rather than within each of the disciplines. For more information on specific Content Standards for the specific science disciplines and levels that you teach, refer to http://www.nap.edu/readingroom/books/nses/index.html.

There is great value of working in vertical teams, grades 7 to 12. By aligning curriculum from grade to grade it can be insured that many more students will have access to the most rigorous curriculum offered at their schools—AP courses. The College Board has identified the key areas in which students need preparation in order to progress in science. These skills involve working collaboratively to obtain, record and present scientific data in verbal, written and graphical forms. The College Board encourages science teachers to have students improve their ability to write lab reports and scientific papers as well as design and critique experimental designs. It is also important to introduce students to the nature of scientific investigation and how understanding the discipline of science advances our critical thinking skills.

Science Content Standards for California Public Schools, Grades 9–12

As a resource for teachers using this guide, the following pages outlines a matrix that demonstrates the alignment of standards with specific units/activities in the Write Path II Science Teacher Guide. The matrix is divided into the following content and expectation strands: Physics, Chemistry, Biology/Life Sciences and Investigation and Experimentation.

As a further resource, the Unit Overviews, if applicable, will list the specific standard references for the unit's activities.

The Write Path II Science/California Standards Alignment Matrix: Grades 9–12

P= Partially aligned, F= fully aligned

SCIENCE CONTENT STANDARDS	AVID - Write Path II High School Science	
PHYSICS ***Motion and Forces*** 1. Newton's laws predict the motion of most objects.		
a. Students know how to solve problems that involve constant speed and average speed	Unit 7 D: Golf Ball Lab	P
b. students know that when forces are balanced, no acceleration occurs; thus an object continues to move at a constant speed or stays at rest (Newton's first law).	Unit 7 D: Hooke's Law Lab	P
c. Students know how to apply the law F = ma to solve one-dimensional motion problems that involve constant forces (Newton's second law).	Unit 7 D: Hooke's Law Lab, Friction Under Pressure Lab	P
h. Students know Newton's laws are not exact but provide very good approximations unless an object is moving close to the speed of light or is small enough that quantum effects are important.	Unit 7 D: Reaction Rivalry Lab	P
Conservation of Energy and Momentum 2. The laws of conservation of energy and momentum provide a way to predict and describe the movement of objects.		
c. Students know how to solve problems involving conservation of energy in simple systems, such as falling objects.	Unit 7 D: Hooke's Law Lab	P
h. Students know how to solve problems involving conservation of energy in simple systems with various sources of potential energy, such as capacitors and springs.	Unit 7 D: Hooke's Law Lab	P
Heat and Thermodynamics 3. Energy cannot be created or destroyed, although in many processes energy is transferred to the environment as heat.		
a. Students know heat flow and work are two forms of energy transfer between systems.	Unit 7 D: Friction Under Pressure	P
Electric and Magnetic Phenomena 5. Electric and magnetic phenomena are related and have many practical applications.		
a. Students know how to predict the voltage or current in simple direct current (DC) electric circuits constructed from batteries, wires, resistors, and capacitors.	Unit 7 D: DC Circuit Design	F

b. Students know how to solve problems involving Ohm's law.	Unit 7 D: DC Circuit Design	F
c. Students know any resistive element in a DC circuit dissipates energy, which heats the resistor. Students can calculate the power (rate of energy dissipation) in any resistive circuit element by using the formula Power = IR (potential difference) _ I (current) = I2R.	Unit 7 D: DC Circuit Design	P
CHEMISTRY ***Atomic and Molecular Structure*** 1. The periodic table displays the elements in increasing atomic number and shows how periodicity of the physical and chemical properties of the elements relates to atomic structure.		
a. Students know how to relate the position of an element in the periodic table to its atomic number and atomic mass.	Unit 7B: Atomic Theory Lab	P
b. Students know how to use the periodic table to identify metals, semimetals, nonmetals, and halogens.	Unit 7B: Atomic Theory Lab	P
Chemical Bonds 2. Biological, chemical, and physical properties of matter result from the ability of atoms to form bonds from electrostatic forces between electrons and protons and between atoms and molecules.		
a. Students know atoms combine to form molecules by sharing electrons to form covalent or metallic bonds or by exchanging electrons to form ionic bonds.	Unit 7B: Egad! The Crystalline Cube	P
c. Students know salt crystals, such as NaCl, are repeating patterns of positive and negative ions held together by electrostatic attraction.	Unit 7B: Egad! The Crystalline Cube Unit 7B: Atomic Theory Lab	P
h. Students know how to identify solids and liquids held together by van der Waals forces or hydrogen bonding and relate these forces to volatility and boiling/melting point temperatures.	Unit 7B: Atomic Theory Lab	P
Conservation of Matter and Stoichiometry 3. The conservation of atoms in chemical reactions leads to the principle of conservation of matter and the ability to calculate the mass of products and reactants.		
b. Students know the quantity one mole is set by defining one mole of carbon 12 atoms to have a mass of exactly 12 grams.	Unit 7B: Atomic Theory Lab	P
d. Students know how to determine the molar mass of a molecule from its chemical formula and a table of atomic masses and how to convert the mass of a molecular substance to moles, number of particles, or volume of gas at standard temperature and pressure.	Unit 7B: Atomic Theory Lab	P

e. Students know how to calculate the masses of reactants and products in a chemical reaction from the mass of one of the reactants or products and the relevant atomic masses.	Unit 7B: Atomic Theory Lab	F
Gases and Their Properties 4. The kinetic molecular theory describes the motion of atoms and molecules and explains the properties of gases.		
a. Students know the random motion of molecules and their collisions with a surface create the observable pressure on that surface.	Unit 7B: The Popcorn Lab	P
c. Students know how to apply the gas laws to relations between the pressure, temperature, and volume of any amount of an ideal gas or any mixture of ideal gases.	Unit 7B: The Popcorn Lab	P
BIOLOGY/LIFE SCIENCES ***Cell Biology*** 1. The fundamental life processes of plants and animals depend on a variety of chemical reactions that occur in specialized areas of the organism's cells.		
a. Students know cells are enclosed within semipermeable membranes that regulate their interaction with their surroundings.	Unit 7A: Osmoregulation in Goldfish	F
c. Students know how prokaryotic cells, eukaryotic cells (including those from plants and animals), and viruses differ in complexity and general structure.	Unit 7A: Leaf Stomata Investigation	P
4. Genes are a set of instructions encoded in the DNA sequence of each organism that specify the sequence of amino acids in proteins characteristic of that organism.		
c. Students know how mutations in the DNA sequence of a gene may or may not affect the expression of the gene or the sequence of amino acids in an encoded protein.	Unit 7A: The Paper Plasmid: A rDNA Simulation	P
5. The genetic composition of cells can be altered by incorporation of exogenous DNA into the cells.		
d. Students know how basic DNA technology (restriction digestion by endonucleases, gel electrophoresis, ligation, and transformation) is used to construct recombinant DNA molecules.	Unit 7A: The Paper Plasmid: A rDNA Simulation	F
e. Students know how exogenous DNA can be inserted into bacterial cells to alter their genetic makeup and support expression of new protein products.	Unit 7A: The Paper Plasmid: A rDNA Simulation	F
Ecology 6. Stability in an ecosystem is a balance between competing effects.		
b. Students know how to analyze changes in an ecosystem resulting from changes in climate, human activity, introduction of nonnative species, or changes in population size.	Unit 7C: Bioassay of Ammonia on Bloodworms: Finding the LC-50.	P

c. Students know how fluctuations in population size in an ecosystem are determined by the relative rates of birth, immigration, emigration, and death.	Unit 7C: Packums: Determining Population Size	P
Evolution 7. The frequency of an allele in a gene pool of a population depends on many factors and may be stable or unstable over time.		
a. Students know why natural selection acts on the phenotype rather than the genotype of an organism.	Unit 7C: Why Don't Whales Have Legs?	P
Physiology 9. As a result of the coordinated structures and functions of organ systems, the internal environment of the human body remains relatively stable (homeostatic) despite changes in the outside environment.		
b. Students know how the nervous system mediates communication between different parts of the body and the body's interactions with the environment.	Unit 7C: Caffeine Lab	P
f. Students know the individual functions and sites of secretion of digestive enzymes (amylases, proteases, nucleases, lipases), stomach acid, and bile salts.	Unit 7A: Fighting the Stomach Acid Blues Unit 7A: Oh, My Aching Stomach!	P
INVESTIGATION AND EXPERIMENTATION 1. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other four strands, students should develop their own questions and perform investigations.		
a. Select and use appropriate tools and technology (such as computer-linked probes, spreadsheets, and graphing calculators) to perform tests, collect data, analyze relationships, and display data.	**Unit 6: How to Graph Data **Unit 6: Designing Data Tables **Unit 6: Analysis Writing	P
b. Identify and communicate sources of unavoidable experimental error.	**Unit 6: How to Write a Lab Report Unit 7A:Fighting The Stomach Acid Blues, Oh, My Aching Stomach!, Leaf Stomata Investigation, Osmoregulation in Goldfish, The Paper Plasmid: A rDNA Simulation Unit 7B: The Popcorn Lab, Egad! The Crystalline Cube, Atomic Theory Lab Unit 7C: Caffeine Lab, Bioassay of Ammonia on Bloodworms: Finding the LC-50, Packums: Determining Population Size, Why Don't Whales Have Legs? Unit 7D: Hooke's Law Lab, Reaction Rivalry, Golf Ball Labs, DC Circuit Design, Friction Under Pressure	P

c.	Identify possible reasons for inconsistent results, such as sources of error or uncontrolled conditions.	**Unit 6: Experimental Design **Unit 6: How to Write a Lab Report Unit 7A:Fighting The Stomach Acid Blues, Oh, My Aching Stomach!, Leaf Stomata Investigation, Osmoregulation in Goldfish, The Paper Plasmid: A rDNA Simulation Unit 7B: The Popcorn Lab, Egad! The Crystalline Cube, Atomic Theory Lab Unit 7C: Caffeine Lab, Bioassay of Ammonia on Bloodworms: Finding the LC-50, Packums: Determining Population Size, Why Don't Whales Have Legs? Unit 7D: Hooke's Law Lab, Reaction Rivalry, Golf Ball Labs, DC Circuit Design, Friction Under Pressure	P
d.	Formulate explanations by using logic and evidence.	**Unit 5: Is A Hypothesis Provable? **Unit 6: How to Write a Lab Report **Unit 6: Experimental Design	F
e.	Solve scientific problems by using quadratic equations and simple trigonometric, exponential, and logarithmic functions.	Unit 7D: Hooke's Law Lab, Reaction Rivalry, Golf Ball Labs	P
f.	Distinguish between hypothesis and theory as scientific terms.	**Unit 5: Limits of Science	P
j.	Recognize the issues of statistical variability and the need for controlled tests.	**Unit 6: Experimental Design	P
k.	Recognize the cumulative nature of scientific evidence.	**Unit 5: Limits of Science	P
l.	Analyze situations and solve problems that require combining and applying concepts from more than one area of science.	Unit 7A: Stomach Acid Blues, Osmoregulation in Goldfish. Unit 7B: The Popcorn Lab Unit 7C: Bioassay of Ammonia on Bloodworms: Finding the LC-50 Unit 7D: Golf Ball Labs Unit 8: Doing Research in Science	P
m.	Investigate a science-based societal issue by researching the literature, analyzing data, and communicating the findings. Examples of issues include irradiation of food, cloning of animals by somatic cell nuclear transfer, choice of energy sources, and land and water use decisions in California.	Unit 7C: Bioassay of Ammonia on Bloodworms, Packums Lab. Unit 8: Doing Research in Science	P
n.	Know that when an observation does not agree with an accepted scientific theory, the observation is sometimes mistaken or fraudulent and that the theory is sometimes wrong.	**Unit 5: Limits of Science, Human Soul Weighs 1/3000th of an Ounce. **Unit 5: Evidence of the Big Bang	F

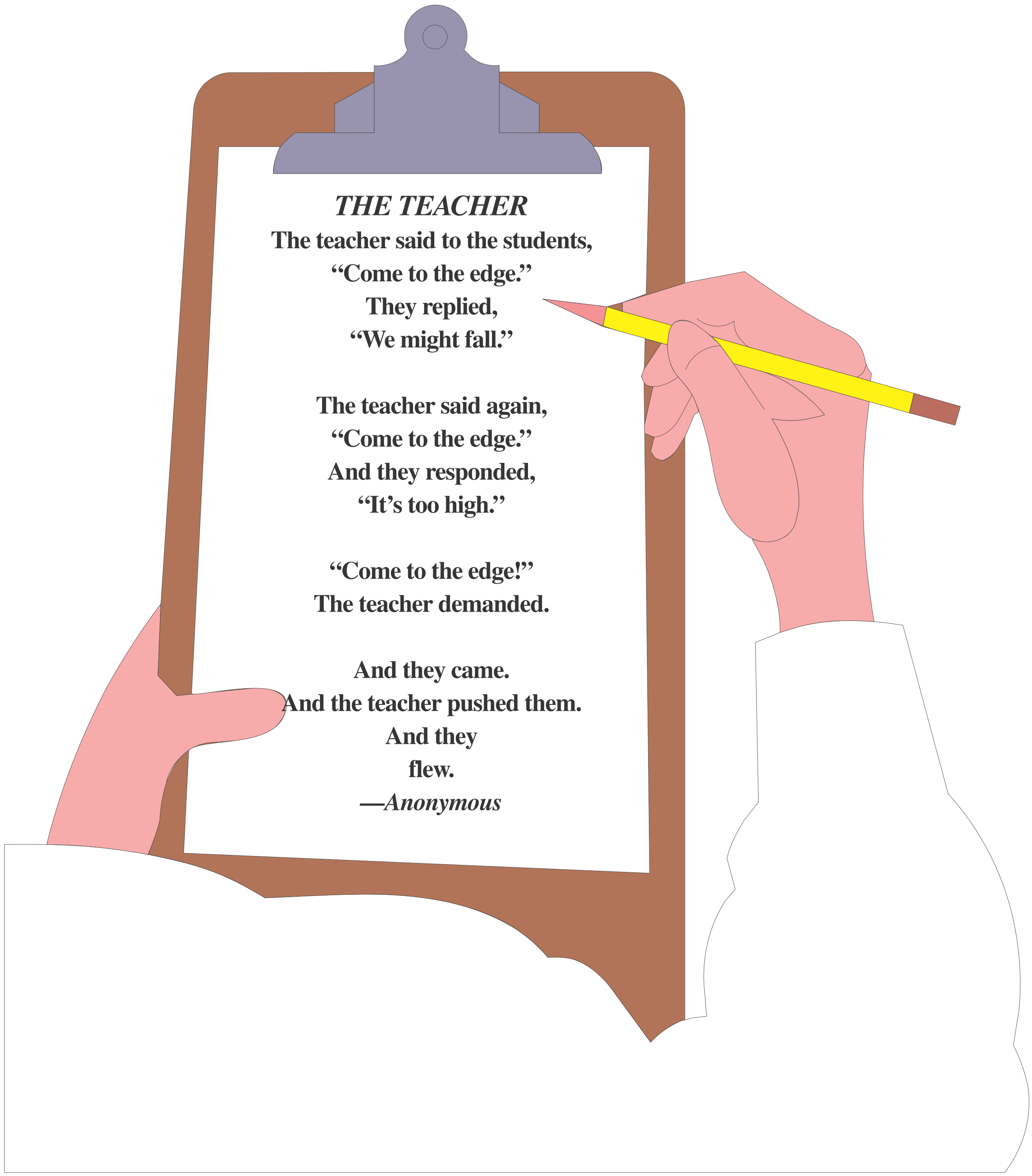
P= Partially aligned, F= fully aligned

** Please note that, for the most part, Units 5 and 6 do not have specific student activities that are aligned to the standard, but do have numerous teacher guidelines and student handouts that provide tools and processes that support the standard.

How to Use This Book

This book is organized into units. Each unit has an overview of the philosophy and big ideas related to the theme. The first four units present a basic framework for learning, understanding, and processing scientific ideas. The activities in each of these units can be used in any order, there is no explicit sequence. Units 5 and 6 present a science specific content framework. In these units, the activities and ideas are placed in a sequential order. The ideas expressed in these two units build to a final product. Unit 7 then applies all of the earlier concepts, pedagogy and content to science labs. Each AP science course is represented. These labs demonstrate how to incorporate writing, inquiry, collaboration and reading into daily science activities. They serve as models to adapt your current labs or those recommended by the College Board. The final unit is a culmination of these ideas to support research in scientific fields.

This publication includes a CD which contains information regarding student handouts and activities and Power Point presentations for selected topics.


THE TEACHER
The teacher said to the students,
"Come to the edge."
They replied,
"We might fall."

The teacher said again,
"Come to the edge."
And they responded,
"It's too high."

"Come to the edge!"
The teacher demanded.

And they came.
And the teacher pushed them.
And they
flew.
—Anonymous

Unit 1: Getting Organized to Learn

Overview

Goal: **To help students physically and mentally organize their learning from pieces of the puzzle into one cohesive whole.**

How we accumulate and organize knowledge, that is, how we receive, sort, classify, and organize our environment is referred to as *schema*. In this unit, methods are introduced for helping students understand the *schema* for organizing and studying valuable and interrelated course material, including homework. Students who have an understanding of how *schema* and building relationships between ideas and concepts help them learn, achieve at higher levels than students without this metacognitive skill.

Have you ever tried to balance your checkbook after a month of not recording any of your purchases? It's easy if you only make three purchases in a given month. However, it can be a nightmare if you have 10–15 transactions per week. Learning can be a bit like that for many students. Check out an average student "notebook." Often you will find papers representing a number of classes stuffed in some sort of binder or shoved into the pockets of a spiral notebook. If you shake the "notebook" hard enough you would probably see all sorts of things fall to the floor, including notes, invitations, random sketches, field trip permission forms, torn edges of paper with cryptic homework assignments, etc. This organizational style may work for some in a regular level class; however, it is not effective for the student in rigorous coursework.

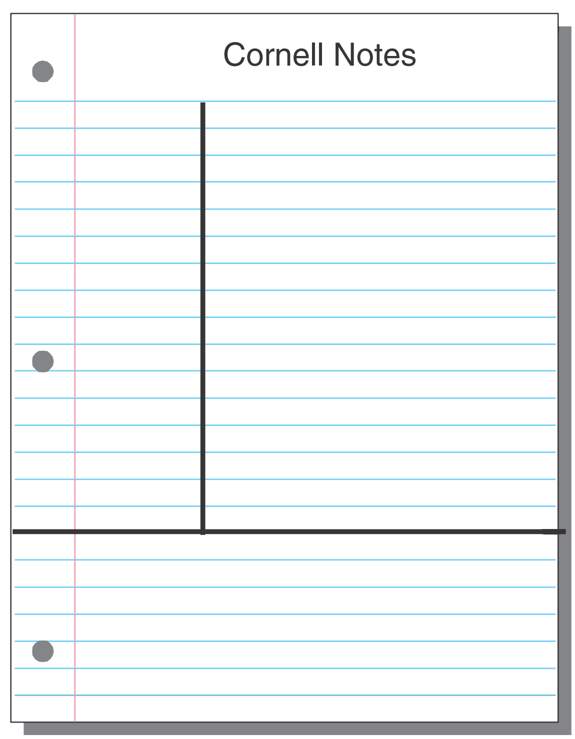
A critical step in becoming an effective learner and a successful student, especially in rigorous courses, is to develop a consistent process for organizing materials. Many teachers of AP and Honors level courses believe and/or assume students already: 1) understand that they need to be highly organized; and 2) possess the requisite skills to organize themselves. In actuality, a large number of students entering these courses today lack organizational and other basic study skills. As a result, many are at a severe disadvantage compared to their more organized peers. To better prepare students to succeed in AP courses, it is critical that teachers teach and reinforce the organizational and study skill strategies specific to the content of science.

There are many ways to organize course content. Many teachers, for example, provide textbooks and handouts aligned to a syllabus in which topics are arranged chronologically and broken into smaller more manageable units. Some teachers mandate student notebooks, in which notes are placed together in one section, labs in another, and homework in a third. Does this organizational approach have a positive impact on student learning? Learning occurs best when a student is able to process and reflect on new information or input. Placing homework in a section of a notebook unrelated to class notes is simply not effective.

Note taking has seemingly become a lost art in high schools. Many students are missing out on the power of class notes. Class notes serve as a guide to learning and a preview of what is tested the majority of the time. When used effectively, notes can be the key to understanding concepts by developing inquiry as a tool for learning science. Developed by Walter Pauk at Cornell University, the Cornell note-taking style creates a study guide for students as well as a forum for reviewing and recalling information.

After students have designed their notes effectively and participated in a unit of study, they are ready to synthesize their learning. Concept maps are visual webs that define relationships between ideas, organize data sets, and delineate and define a student's comprehension and perception of the curriculum, creating a window into their learning. Through this window, teachers have the ability to further shape and broaden student learning through new experiences.

Learning only becomes effective once metacognition, the process of learning, is internalized. Successful people all depend on some system of organization that creates the thinking patterns of their everyday lives. Students are no exception. They require a framework in place in order to become successful at their job: achieving in academia. Teachers must help students to comprehend not only why organization is important for achieving success in school, but also that it is critical for achieving success in the scientific study of the world.



InterActive Notebooks

"I cannot teach anybody anything, I can only make them think." —Socrates

Prior to introducing the spiral notebook with 80–100 pages, make sure students have a spiral notebook with at least 100 pages, copies of the left and right side instructions, table of contents, colored pens/pencils, and a glue-stick. You may provide scissors, tape, markers, etc. if you wish.

Timeline

It will take 60 minutes to introduce students to the notebook elements, show the Power Point presentation, and set up the notebooks for the year.

WIC-R Strategies

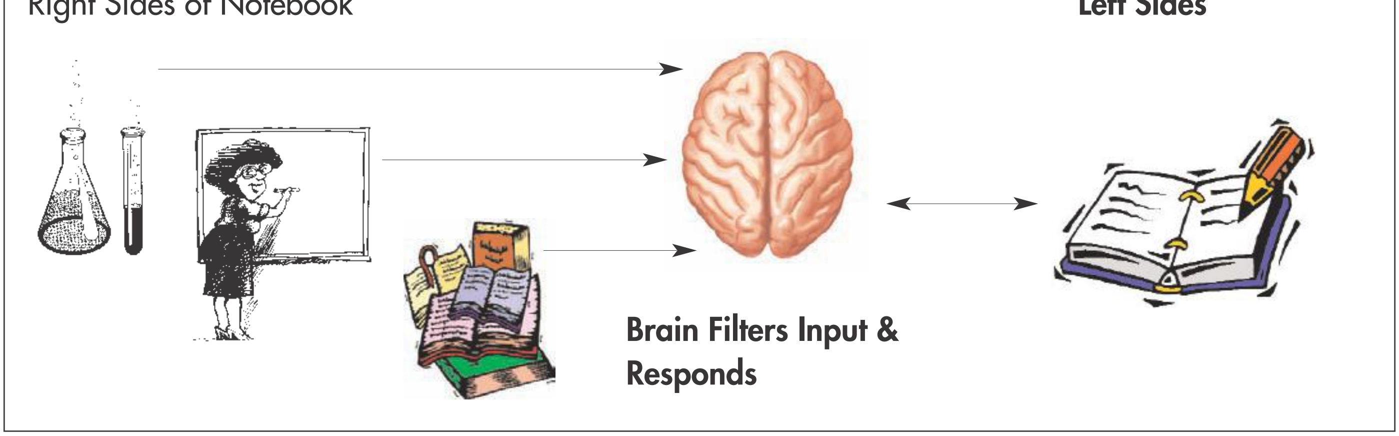
- Writing
- Inquiry
- Collaboration
- Reading

Concept Statement

Students, even AP students, need help with organization. In science, we frequently keep track of our work by using a lab notebook with numbered pages where we record procedures for experiments and data and musings on the interpretations of the data. Science students can participate in a similar process by using InterActive Notebooks in your class. In this notebook, students use both sides of the spiral (analogous to the right and left brain hemispheres) to take in information (input), do something with the information (filter), and then use the information to produce a product (output).

One of the main advantages to using an InterActive Notebook is that students take ownership of their work; grading is holistic, and students can develop 'knowledge over time' and reflect on their own learning. Parents are invited to look at their student's work and to respond to it and communicate with you. When it comes time to review for the AP exam, students have a chronological record of their work all in one place.

InterActive Notebook Schematic



Lesson Plan

1. Read and review all the information on InterActive Notebooks before beginning.
2. Start your own skeleton notebook with pages numbered and beginning pages glued in. (See sample notebook set-up on this page.)
3. Use the Power Point presentation (or make overhead slides) to introduce students to the InterActive Notebook. Distribute Student Handouts 1–7.
4. To open or end your class periods, regularly assign writing prompts that ask students to reflect on, extend, or interpret what they have been learning.
5. Instruct students to use the right side pages for lecture notes, video notes, lab preparation, and text book notes. The left side is for interacting with the information on the right side. (See student samples.)
6. At the end of the unit, have students use the reflection page to respond to their learning in the unit. Parents are expected to comment also; students can glue in the sample parent review page at the end of the unit.
7. Review and grade the notebooks early on to correct any mistakes with format or instructions. The authors have used InterActive Notebooks for open house presentations to show parents how their students will be documenting their work throughout the year and to share the parent review page.

Project Requirements and Rubrics

See the scoring rubric. Notebooks can be graded at the end of each unit. One of the required elements is that students reflect on their work regularly and discuss their learning with a significant adult (see student sample).

Sample InterActive Notebook Set-up: Cover page plus first seven pages. (Note: Samples of all pages referred to below are included in this unit.)

(inside cover)	**(right side) 1**	**(left side) 2**	**(right side) 3**
Students glue/tape in a copy of the InterActive Notebook scoring rubric.	Notebook Title Page: Course, Teacher, Room, Student's name, etc. (Student constructed)	Students glue/tape in copy of left-side guidelines.	Students glue/tape in a copy of right-side guidelines.

(left side) 4	**(right side) 5**	**(left side) 6**	**(right side) 7**
Students glue in a copy of the Student Reflection page guidelines.	Students glue in copy of parent review page.	Students construct a title page for the first unit of study. Title: Graphic: Date:	Students glue in the table of contents for the first unit.

Text for Power Point slides (on the companion CD).

Interactive Notebooks

An innovative strategy for students and teachers

What is an Interactive Notebook?

Interactive Notebooks are a tool to strengthen student learning of curriculum (the input) through increased student participation (the output).

Simply put, more bang for the buck !

Why use Interactive Notebooks?

The Student Perspective

- ☺ Claims ownership & responsibility
- ☺ Chooses ways to process information and gets to reflect on what's been learned.
- ☺ Includes more learning styles.
- ☺ Develops higher-level thinking skills.
- ☺ Organizes learning over time.
- ☺ Work doesn't get lost!

The Teacher Perspective

InterActive Notebooks:

- Make learning more democratic and inclusive.
- Motivate participation—students own their work.
- Provide a record of curriculum lessons and tools for self-evaluation.
- Allow easy monitoring of student progress.
- Reduce time spent evaluating student work.
- Provide 'real' student feedback on each unit.
- Can be used as a parent-teacher communication tool.

Materials

- 8 1/2 x 11 spiral notebook (min 80 pg) - one per student
- Pens/pencils with erasers
- Glue sticks/tape/rubber cement
- Colored pencils or pens
- Highlighters
- Scissors

Other Helpful Hints for Teachers

- Keep a skeleton sample of the notebook without answers. Students who are absent can see what items went into the notebook and get lecture notes from other students.
- Provide feedback immediately by checking a few notebooks in the first few days of class. You can pick up a few notebooks a day using the 'lottery' system.
- Graded work can be added after it is returned. Have students leave a labeled space in their notebooks for the work.
- Occasional open notebook quizzes inspire great notebooks and demonstrate the usefulness of good note taking skills.
- Use the notebooks for parent conferences and for teacher-parent feedback; encourage parents to look over their students' notebooks at periodic intervals.
- Share excellent student work often!

FAQs for Teachers

1. **Do all students have the same pages or is each student's notebook different?**

   Students have natural variation in the size of writing and the amount of detail they use in note taking. As long as the pages are numbered and follow the constructed table of contents, variation is expected.

2. **What if I'm not sure if the work goes on the left side or right side?**

   Ask yourself... "Is this input (you giving them information) or output (students doing something with the information)." Input goes on the right side, output on the left. However, if you accidentally reverse the pages, it really has minor impact. Remember, this is the students' work, and they are expected to show evidence of their learning. The InterActive notebook is a tool that helps scaffold students' knowledge.

3. **How do I include journal prompts?**

   Journal writing is thinking made visible. The authors used prompts daily as a warm-up exercise or as a closure activity. Writing is not a passive activity—it requires mental construction. Students should use their notebooks as a reflection tool regularly.

4. **How much of the grade is this?**

   It depends on your grading scheme. The authors used journal writing as part of the homework and classwork grade (25%) and as a measure of students' participation and engagement.

5. **How often should I collect the notebooks?**

   Again this depends on your grading practices. It's a good idea to grade them regularly, for example, at the end of every unit when there has been enough material for the students to reflect on. One way to grade them is to have 'notebooks are due week' and call names in the lottery system. By pulling 10 notebooks per class, the notebooks can be graded in rotation and you won't have 150 sitting on your desk on Friday.

6. **How do I include lab work?**

   The lab preparation and data collection can be recorded in the InterActive Notebooks. If you require students to submit a formal lab report, this can be stapled into the notebook after it is graded.

7. **Where is the W • I • C • R?**

   Writing, Inquiry, Collaboration, and Reading (WIC-R) are imbedded into all aspects of the notebook. Sometimes the activities overlap; however, all are represented in the production of this type of student work.

Keeping InterActive Notebooks in Science

InterActive Notebooks will be used in this class to help you learn and remember key scientific concepts. Why does this type of notebook work? This notebook style uses both the right and left brain hemispheres to help you build neural networks. By providing space for you to record information and refer to it quickly, this too increases your ability to remember and use the information later. You'll also have an opportunity to interact creatively with the new knowledge you're gaining.

InterActive Notebook supplies due by ___________________

1. An 8½ x 11 spiral notebook with at least 80–100 pages
2. 2 glue sticks
3. Highlighters of different colors and/or colored pencils
4. Pen and pencil with an eraser

Instructions

See the sample below for the set-up for the first seven pages. Number all the pages that follow in the upper right hand corner. Left sides pages are even; right side pages are odd.

Left pages = output (even numbered pages)

The left spiral page shows your understanding of information. Basically it's your manipulation of the information from the right side. You work with input from the right side, but **present** it in your own way.

Right pages = input (odd numbered pages)

The right page is for writing down information you are given or you have read—when your teacher lectures, or you get input from books, videos, or speakers. When you get information about how to set up a lab, or safety requirements—this goes on the right page.

(inside cover) Students glue/tape in a copy of the InterActive Notebook scoring rubric.	**(right side) 1** Notebook Title Page: Course, Teacher, Room, Student's name, etc. (Student constructed)	**(left side) 2** Students glue/tape in copy of left-side guidelines.	**(right side) 3** Students glue/tape in a copy of right-side guidelines.
(left side) 4 Students glue in a copy of the Student Reflection page guidelines.	**(right side) 5** Students glue in copy of parent review page.	**(left side) 6** Students construct a title page for the first unit of study. Title: Graphic: Date:	**(right side) 7** Students glue in the table of contents for the first unit.

Scoring Rubric

5+ Notebook exceeds all expectations in all areas; demonstrates superior understanding units of material, extensive left-side processing and well-developed Cornell notes; includes review materials.

5.0 **A** Contents are complete, dated, and labeled; left sides/right sides show mastery pattern of organization; notes are Cornell-style with excellent questioning that goes beyond basic requirements; notebook integrates other sources of information; demonstrates extensive left-side processing of information; uses color throughout in a meaningful way; includes effective diagrams and pictures; shows impressive, in-depth reflection about the work; includes signature and comments of significant adult; pages are numbered correctly.

4.5 **B+** Contents are dated and labeled with no more than one assignment missing; left sides/right sides show well-developed pattern of organization; notes are Cornell-style with good questioning; demonstrates satisfactory amount of left-side processing of information; uses color in a meaningful way; includes effective diagrams and pictures; shows thorough reflection about the work; includes signature of significant adult; pages are numbered correctly.

4.2 **B** Contents are mostly complete (~2-3 missing/incomplete pieces), dated and labeled; left sides/right sides show basic pattern of organization; notes are Cornell-style with questioning; demonstrates some left-side processing of information; uses color; includes diagrams and pictures; shows reflection about the work; has significant adult signature; pages are numbered correctly.

4.0 **C+** Contents are somewhat complete (~4-5 missing/incomplete pieces), dated, labeled, and legible; notes are Cornell-style with some questions; left sides/right sides show developing pattern of organization; left sides include some processing of information; uses color; includes diagrams and pictures; has reflection; has signature of significant adult; pages are numbered correctly.

3.7 **C** Contents are somewhat complete (max. 5 missing/incomplete pieces), dated, labeled, and legible; notes are Cornell-style; left sides/right sides show developing pattern of organization; left sides include some processing of information or minimal processing; work includes diagrams and pictures; has reflection; pages are numbered correctly.

MAXIMUM SCORE WITH NO SIGNIFICANT ADULT SIGNATURE AND COMMENTS

3.2 **D** Contents are partially complete, dated, labeled, and legible; notes are Cornell-style; left sides/right sides show random pattern; few left sides include processing of information; has minimal reflection; pages are numbered.

2.0 Contents are incomplete; some attempt at dating and labeling of entries is made; left sides/right sides show little pattern; minimal left-side processing of information; no reflection; pages are numbered.

1.0 Notebook turned in; few assignments are included; most inserts not attached to notebook; too incomplete to evaluate.

InterActive Notebooks: Left Sides

The left spiral page (even number) demonstrates your *understanding* of the information from the right-side page (odd number). You work with the input, and INTERACT with the information in creative, unique, and individual ways. We'll use the "clock" questions to help accelerate your learning and focus your attention on big science concepts.

What goes on the left side?

OUTPUT GOES ON THE LEFT SIDE! EVERY LEFT SIDE PAGE GETS USED!

ALWAYS USE COLOR—it helps the brain learn and remember.

What else goes on the LEFT side?

- Brainstorming
- Pictures
- Venn diagrams
- Other diagrams
- Reflections
- Flow charts
- Significant statements
- Responses to the "clock" questions
- Mind-mapping
- Concept maps
- Drawings
- Commentary
- Writing prompts
- Flights of fancy
- Hypothesis development

12 Make a visual illustration explaining the topic.

1 What's my study plan to learn this information?

2 What's the best way to remember this topic?

3 Write the lyrics for a song on this topic.

4 Make ____ Vocabulary Cartoons from this topic.

5 Paraphrase this information into one sentence.

6 Write four "What if…" statements about this topic.

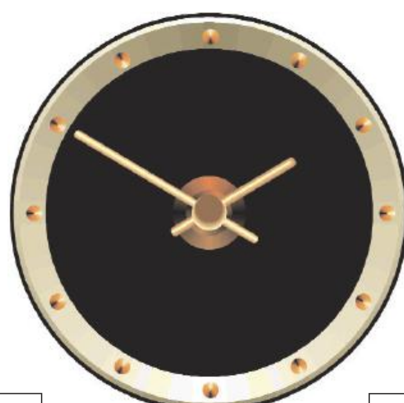
7 Write a letter to ________ about this topic.

8 Create an analogy and a visual for this topic.

9 Write and solve _____ problems using this information.

10 Use a Venn diagram to compare these two ideas.

11 What do I already know about this topic?



InterActive Notebooks: Right Sides

What goes on the right side spiral page?

INPUT GOES ON THE RIGHT SIDE (ODD NUMBER)!

Always start the page by recording the date and subject title at the top.

- The right side spiral has only **odd**-numbered pages
- The right spiral page is for **writing down** information you are **given in class.**
- When the teacher lectures, you take notes on the right side.
- When you take **book notes** or video notes, they go on the right side. **ALWAYS.**
- You may use **Cornell-style** notes on the right pages.
- Vocabulary words and their "book" definitions go on the right side.
- Notes for labs and **lab instructions,** procedures, and materials.
- Teacher questions and sample problems.
- Any other type of **INPUT** you get in class.

Use Cornell-style notes to take lecture and video notes in class. Use them also for text notes from your book.

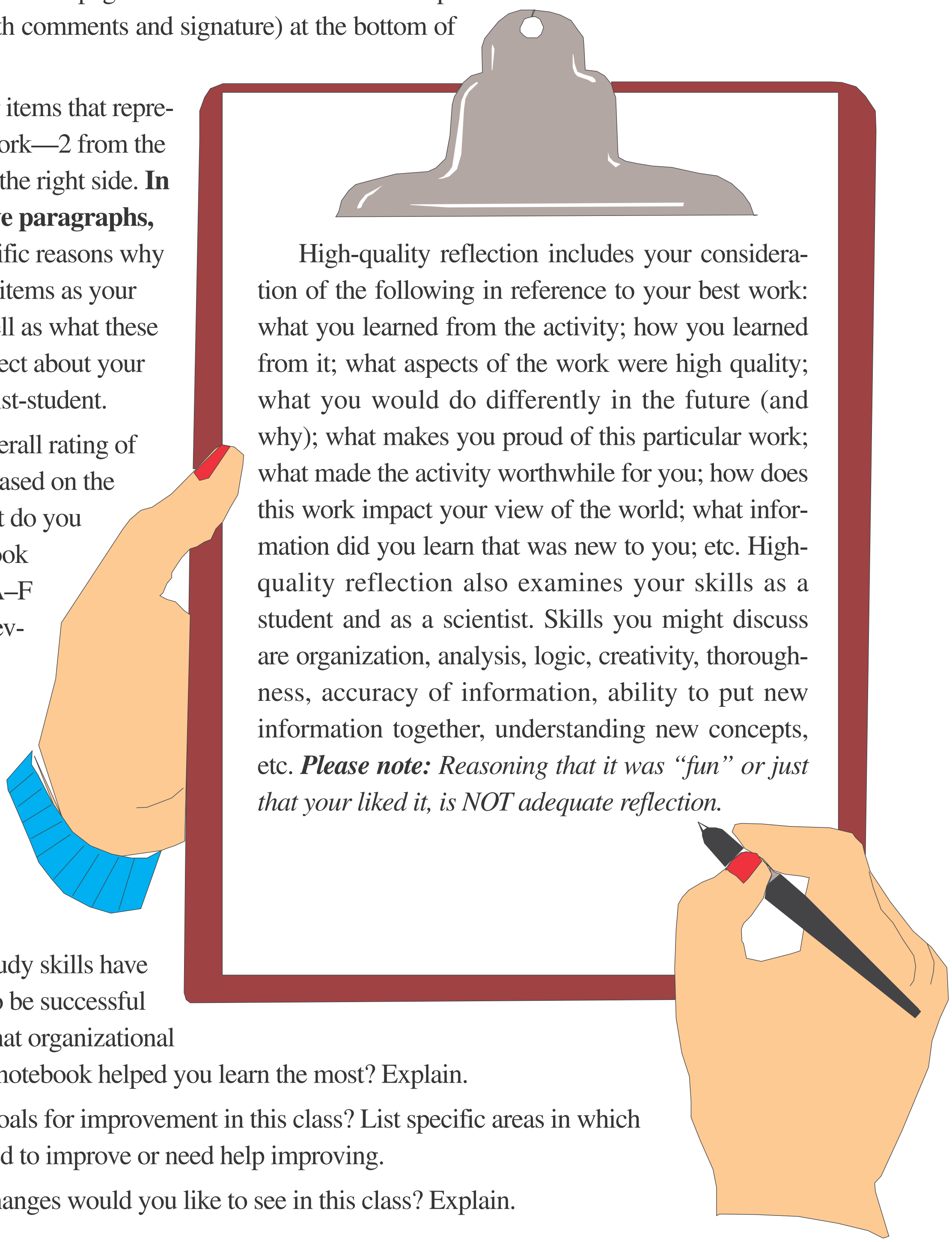
Sample Cornell-Style Notes

Student Questions	**Factual Information**
1. Why are plants green instead of blue or red?	Scientists note that plants are green. Many hypotheses have been proposed to understand plant color.
2. How does photosynthesis work to make food?	Photosynthesis means 'to put together with light' meaning that plants use a process to produce food and energy from light.
3. What's the difference between transmit and absorb?	Plants are green because they transmit green light.
* Ask in class tomorrow: What is the key difference between Photosystem I and Photosystem II. Do all plants need both? What about shade plants?	Photosystem I: Sun's energy breaks water in two. Electrons are set free and boost the levels.... Chlorophyll absorbs the energy during sunlight hours. NADPH+....

Keeping InterActive Notebooks in Science: *The Reflection*

Toward the end of each unit, you will be called upon to reflect upon your work. This writing sample begins on the left side on the notebook and continues on the right. While there is no required length, high quality reflection uses 1–2 pages of the notebook. Attach the parent review form (with comments and signature) at the bottom of the right-hand page.

1. Select up to four items that represent your best work—2 from the left side, 2 from the right side. **In several reflective paragraphs,** address the specific reasons why you chose these items as your best work, as well as what these assignments reflect about your skills as a scientist-student.
2. Indicate your overall rating of your notebook based on the 1–5 rubric. What do you think this notebook deserves on an A–F scale? Include several sentences using specific details, on why you've chosen this rating. Has your notebook improved from past notebooks?
3. What specific study skills have you employed to be successful in this class? What organizational strategies in the notebook helped you learn the most? Explain.
4. What are your goals for improvement in this class? List specific areas in which you feel you need to improve or need help improving.
5. What specific changes would you like to see in this class? Explain.



High-quality reflection includes your consideration of the following in reference to your best work: what you learned from the activity; how you learned from it; what aspects of the work were high quality; what you would do differently in the future (and why); what makes you proud of this particular work; what made the activity worthwhile for you; how does this work impact your view of the world; what information did you learn that was new to you; etc. High-quality reflection also examines your skills as a student and as a scientist. Skills you might discuss are organization, analysis, logic, creativity, thoroughness, accuracy of information, ability to put new information together, understanding new concepts, etc. ***Please note:*** *Reasoning that it was "fun" or just that your liked it, is NOT adequate reflection.*

InterActive Notebook: Parent Review

Dear Parent/Significant Adult:

This interactive notebook represents your student's learning to date and should contain the work your student has completed in class such as notes, homework, class work, reflection on the unit, etc. It should be neat in appearance, have all materials glued in, include color, and have about three pages of materials for each day of class. In order to initiate and continue communication between you, your student, and me, I ask that you please take some time to look at this notebook with him/her, read the reflection, and comment on your student's work to date. Some ideas to comment on are:

- The work we found most interesting was... because...
- What does the notebook reveal about your student's learning habits or talents?
- My student's biggest concern about this class is...
- The biggest improvement my student is making is...

Parent/Significant Adult Signature

Comments? Questions? Concerns? Feel free to contact me at ____

InterActive Notebook - Table of Contents

Unit______________________________ Chapters__________ Date______________

Left-Side Items	Page	Right-Side Items	Page
1		1	
2		2	
3		3	
4		4	
5		5	
6		6	
7		7	
8		8	
9		9	
10		10	
11		11	
12		12	
13		13	
14		14	
15		15	
16		16	
17		17	
18		18	
19		19	
20		20	
21		21	

Quality Rubric Rating: __________ x Value Factor ______ = Total Score _____/____

GLUE your table of contents on the first right-hand page of the new unit, after the title page.

Schema 1: Random Numbers

Timeline

20–30 minutes

WIC-R Strategy

- Inquiry

Materials Required

- Overhead Transparency ("*Schema*… What's That?")
- Student Handout ("Random Numbers"), one per student
- Stop Watch/Timer

Concept Statement

Schema defines how people organize and store information. *Schema* provide the mental shortcuts to help us absorb the bombardment of stimuli from a complex world.

This short activity will show students in a very concrete way how *schema* operate to help us make mental short cuts and to help us understand information in a new, deeper way. As they study difficult conceptual constructs in science, students will build new schema, either individually or as a group, in which they actively link old knowledge to new.

Lesson Plan

Use the provided overhead transparency to introduce students to the concept of schema.

1. Distribute student handout, then tell students to keep the papers face down until you are ready to begin timing. *Have a timer or stop watch ready.*
2. Tell your students they will be taking a test—one of many—to find out what kind of thinkers they are.
3. Tell them to turn the paper over and to find and circle the numbers on the page—IN ORDER—beginning with the number 1.
4. Give students about 60–75 seconds to complete the task.
5. Go around the room and ask for the highest number found. Ask what strategies they used to find the numbers (3–4 students randomly chosen).
6. Tell students about *schema* (from previous section). Explain that *schema* and a deeper understanding of how their brains work will make them more efficient and smarter learners—both of which they'll need for success in AP Science.
7. Put an **overhead transparency** of the activity sheet on a surface that allows you to draw the quadrant (see *schema* answer key). You have just graphically provided a *schema* to organize the random numbers—which are no longer random.
8. Give students 15–20 seconds to find as many more numbers as possible on the activity sheet.
9. Discuss how this can be applied to other information they have learned in the past.

Project Requirements and Rubrics

This activity is best left ungraded. If students leave with an 'ah-ha' experience, and know more about how their brains function, the goal has been met.

SCHEMA... What's that??

People 'construct' meaning based on their store of memories: everything they have ever sensed, experienced, and learned.

SCHEMA = HOW people organize and store information in their heads. *Schema* reflect the experiences, conceptual understandings, attitudes, values, skills, and strategies you bring to a reading situation.

Schema provide mental shortcuts to help us absorb the bombardment of stimuli from a complex world.

Schema function in three ways:

1. Give a **framework** to understand science text, how to read it, and how to fill in gaps.
2. Help you **organize** text information and remember what's been read.
3. Help you **elaborate information** involving deeper cognitive levels of insight, memory, judgment, and evaluation.

Random Numbers

3 47 87 27 11 2 46 86 26 10

63 55 39 79 62 54 38 78

59 19 35 58 18 34

83 71 67 82 70 66

51 43 75 23 50 42 22

15 31 7 14 30 74 6

88 85

4 48 28 12 1 45 25 9

64 56 40 80 61 53 37 77

60 20 36 57 17 33

84 72 68 81 49 69 65

52 44 24 41 73 21

16 32 76 8 13 29 5

3 47 87 27 11 63 55 39 79 59 19 35 83 71 67 51 43 75 23 15 31 7	2 46 86 26 10 62 54 38 78 82 58 18 34 70 66 50 42 22 14 30 74 6
88 4 48 28 12 64 56 40 80 60 20 36 84 72 68 52 44 24 16 32 76 8	85 1 45 25 9 61 53 37 77 57 17 33 81 49 69 65 41 73 21 13 29 5

Schema 2: Joan's Plant

Timeline

20–35 minutes

WIC-R Strategies

- Writing
- Inquiry
- Collaboration

Materials

Overhead Transparency ("Joan was a manufacturer.")

Concept Statement

This activity leads students into a subsequent discussion about inference and alternative hypotheses. Students will be constructing a hypothesis based on cause and effect (and limited data). In this case, they know the effect and are trying to deduce the cause. It is also a good exercise to demonstrate schema in action—what we know about or have experienced will show up in our hypotheses as we try to connect a new situation to what is already known. This activity can also lead into a discussion of researcher bias and how scientists look for an explanation that best explains the data—in this case, a dead Joan. It can also show students how scientific interpretations are always tentative, since having more data can influence causal explanations. *Note: The object of this exercise is NOT to get the 'right' answer, but to have students begin to explore how what they already 'know' influences what they 'see' in another situation. There are several alternative hypotheses that will fit the data presented.*

Lesson Plan

1. Project the overhead transparency. "Joan was a manufacturer. She lived far from her plant. She saw strange puddles around her plant, but paid no attention. Why did she die?"
2. Ask students to write, individually, why they think Joan died and to draw a picture (graphic representation or model) of the situation. (Allow 5–7 min.)
3. Break students into inquiry groups to share and discuss their interpretations. Have each group pick one or two hypotheses about why Joan died and share with the class. (Accept all answers and make no commentary—in real science life, we don't know if we're correct, so peer feedback is important.)
4. Have the class determine the 'best' hypothesis and the reasons why.
5. Have students write about what they learned in this activity and how they think it pertains to the scientific endeavor.
6. One possible scenario is that Joan is a bee who picked up insecticide at her plant that was far away from her hive. Do not feel obligated to tell students this scenario. A questioning and curious mind is the best scientific tool we have.

Project Requirements and Rubrics

Since this is a writing-to-learn exercise, it is best left ungraded, but you should require student participation in the discussion, groups, and activity. A simple credit (turned in) or no credit (not turned in) should suffice.

Joan was a manufacturer. She lived far from her plant. She saw strange puddles around her plant, but paid no attention.

Why did she die?

Cornell Note Taking

Timeline

30+ minutes and ongoing. *Allow 15–20 minutes to discuss how the use of Cornell Notes will enhance student learning of AP science and go through a sample demonstration. Three minutes will be needed to set up the paper for notes. The total lesson time will depend on the topic you are covering. At the end of the period, have students create left-side questions (or assign for homework).*

WIC-R Strategies

- Writing
- Inquiry
- Collaboration
- Reading (if assigned)

Materials

- Science CD (Power Point)
- Overhead Transparency ("The Cornell Note-Taking System")
- Student Handout ("Cornell Note-Taking Format")

Concept Statement

As teachers we understand the importance of good notes. Students, on the other hand, view notes as boring busy work. They often don't know how to take good notes, much less use them as study tools. Cornell note taking not only helps students take notes in an organized way, but also requires that students work with the notes to process information. Students need to be explicitly taught how to take good science notes—don't assume they are learning this skill in their other classes.

Lesson Plan

1. Using the Power Point on the companion CD, open the "Cornell Notes in Science" and review the basic concepts with the students.

2. Ask students how they currently take notes. How do they decide what to write down? What do they do with their notes later? You may want to share how you learned how to take and use notes in college.

3. Use the overhead transparency to set up a Cornell note taking page with students. A blank sample Student Handout is included for your use. (*Note:* College bookstores sell Cornell paper notebooks, which some students may be interested in buying.)

4. Model note taking on the large right-hand side for the lesson you are presenting. Talk about why you are noting specific items. This shows them how you process the information and lets them into your metacognitive practice—thinking about thinking.

5. Show students how to use the left-side column immediately following the lesson. Introduce the three main question types: (1) *Clarifying:* these are the *who, what, when,* and *where* questions. (2) *Purpose and Consequence:* these are the *how* and *why* questions. (3) *Linking:* these questions ask 'so what?' and 'what are the implications?' All three types are useful, but types (2) and (3) are higher level and take more practice.

6. Following the lecture (or text reading), have students summarize and/or reflect on what they've learned from the notes. Model an acceptable summary/reflection for students. Ask students, "So what do you think I expect you to know?"

7. Assign students to complete the question section of the notes (left side).

8. At the start of the next class period, have students review by covering up the right-side information and answering the questions from the left side. Highlighters and different pen colors help students emphasize various key points. This models a process for moving information from short-term memory into long-term memory.

The Cornell Note-Taking System

Name/Date/Unit/Chapter

6cm ◄——► Cues & Questions	15cm ◄——————► Note-Taking Column
	1. **Record:** During the lecture, use the note-taking column for the lecture/Power Point or film, using abbreviations and short sentences. Note key vocabulary and use highlighters! 2. **Questions:** During class or as soon as possible, write questions based on the notes in the right-hand column. Writing questions helps to clarify meaning, shows connections, builds schema, and strengthens memory. You will be ready to ask the teacher the questions you are unclear about during the next class. Also, writing questions gets you ready for the exam and will speed up your studying time later on. 3. **Recite:** Cover the note-taking column with a sheet of paper. Then, looking at the questions or cue words in the question and cue column only, say aloud, in your own words, the answers to the questions, facts, or ideas indicated by the cue words. 4. **Reflect:** Reflect on the material by asking yourself questions, for example: “What’s the significance of these facts? What principle are they based on? How can I apply them? How do they fit in with what I already know? What’s beyond them?” 5. **Review:** Spend at least ten minutes **every week** reviewing all your previous notes. If you do, you’ll remember more, learn tricky vocabulary, and be ready for the exam.
Summary: After class, use this space at the bottom of each page to summarize the notes.	

Cornell Note-Taking Format

Topic ______________________ Unit ______________ Date ______________

Clarifying, Purpose and Linking Questions	Notes: Information, Vocabulary, Main Points, Formulas, etc.
Summary	

Tips for Taking Cornell Notes

The following tips will greatly enhance your notes.

Set Up Your Paper

- Put name, class, and date in the upper right-hand corner.
- Give all notes a title.
- Draw a line (or fold your **paper**) down the length of the paper about one-third of the way from the left-hand margin.
- Set up a number of **pages**, leaving room for summary notes. This will allow you later to better organize your notes and make significant comments.

Take Notes

- Paraphrase the text or lecturer in the right column.
- Listen carefully to identify important information. Concentrate on understanding what the ideas are.
- Use memory cues such as CAPITAL LETTERS, underlining, stars, pictures, or abbreviations.
- Don’t worry about spelling.
- Use abbreviations or a shorthand that works for you. Do not try to write down everything word for word.
- If you are absent, be sure to get someone else’s notes. Write your **own** comments in the left-hand column.

After Class

- Edit your notes as soon as possible. Reread them and make additions and clarifications, as needed.
- Work with a partner when you find it useful.
- Use a highlighter or different colors to emphasize important points.
- Make a **note** to ask questions about confusing items at the next class session.
- Fill in the left column with questions, symbols, and memory clues.

Review Your Notes

- Review notes regularly (not just before a test): first, after class, then every two or three days, and finally before a test.
- Cover the right column with blank **paper**.
- Use the questions, symbols, and memory clues in the left column as cues either to rewrite the information in the right column or to say it aloud.
- Reflect on the notes. Summarize them and try to relate them to personal experiences.

Developed by Cyndy Bishop, SDCOE and Gerry Kirk, Helix Charter HS

Note Taking: Tips for Lectures

Be an Active Listener

- Think about what is being said.
- Think about how what is being said relates to other points in the lecture and ideas from discussion/reading/other subjects.
- Ask questions.

Be Aware of Lecturer/Speaker Organization

- Listen for the speaker to forecast organization of the lecture (e.g., phrases like, “Today I want to talk about,” or “By the end of this lecture, you should be convinced that”).
- Look for lecture outlines on the board or handouts.
- Use arrows/lines/circles/numbers to connect related ideas.

Use the Speaker’s Style to Identify Important Points

- Become familiar with the speaker’s style.
- Listen for important points that might be emphasized when the speaker:
  - pauses or slows down;
  - repeats a point;
  - modulates the volume of his/her voice;
  - uses introductory phrases;
  - writes on the board; and
  - generalizes or uses visual aids.

Keep up With the Speaker

- Write only the important ideas such as names, places, dates, events, examples, terms, definitions, causes, effects, evaluations, cross references: Make it brief, but clear.

Be Alert to Speaker’s Stance

- Some lecturers attempt to persuade as well as inform listeners; when applicable, note ideas/references/opinions that provide insight into speaker’s point of view.

Review Notes Shortly After a Lecture

- Develop study questions and identify main ideas.
- Fill in details for clarity.
- Identify information that is unclear and/or questions that need to be answered; write and mark questions in the text of notes or at the end where they will be easily found; get answers to the questions from other students, the teacher, or other texts.
- Look up and add definitions of new terminology.

- Add symbols to highlight important ideas.
- Delete irrelevant information.
- Review overall organization of the material; add symbols to make organization clear or rewrite for clarity as needed.
- Incorporate cross references to other texts and notes.
- Write a summary of notes, using significant statements.

Note Taking: Tips for Textbooks and Other Readings

Be an Active Reader

- Think about the reading.
- Consider the ways that portions of the text relate to the text as a whole; think about how the text relates to ideas from lectures, discussions, and other subjects.
- Generate questions (e.g., about the meaning of new words/terms, about why portions of the text are italicized or underlined, about why emphasized points are important).
- Examine and understand the significance of visuals (e.g., diagrams, graphs, charts, photos, artwork).

Be Aware of Text Organization

- Look for the pattern of elements like chapter/subsection headings, summary points, graphics.
- Know where to find the index and glossary.

Use the Style of the Text to Identify Important Points

- Become familiar with the typefaces, symbols, borders, graphics, colors, and page layouts that highlight main ideas and key terms.

Be Alert to the Writer's Goal

- Some texts attempt to persuade as well as inform listeners; when applicable, highlight ideas, references, and opinions that seem significant to writer's point of view.

Take Notes While Reading

- Incorporate chapter headings, key terms, meaningful examples, important graphics into notes.
- Write only the important ideas; make it brief, but clear.
- Paraphrase text to capture meaning and reduce volume.
- Use symbols to highlight significant material and/or areas for further study.
- Use headings, subheadings, and review questions within the text to generate study questions and main ideas for left-hand column of notes.
- Incorporate original questions raised by text into notes.

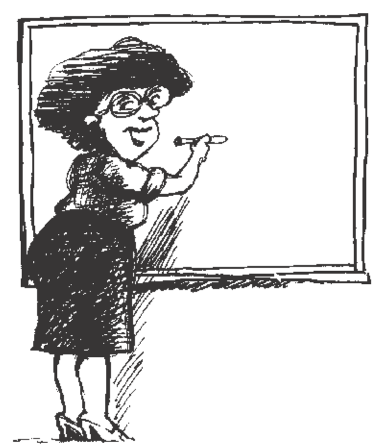
Review Textbook Notes

- Develop study questions and identify main ideas.
- Fill in details for clarity.
- Identify information that is unclear and/or questions that need to be answered; write and mark questions in the text of notes or at the end where they will be easily found; get answers to the questions from other students, the teacher, or other texts.
- Look up and add definitions of new terminology.
- Add symbols to highlight important ideas.
- Delete irrelevant information.
- Review overall organization of the material; add symbols to make organization clear or rewrite for clarity as needed.
- Incorporate cross references to other texts and notes.
- Write a summary of notes, using significant statements.

Note Taking: Tips for Videos and Guest Speakers

Consider the Subject and Purpose

- Notes from video and film viewing for information (e.g., depiction and description of tide patterns, narration about an historic period) are much like lecture notes, guided by similar verbal cues.
- Notes from video and film viewing for enrichment (e.g., dramatic portrayal of history, the stage version of a play) can be enhanced by style clues that may contribute to meaning. Look/listen for the significance of:
  - — names;
  - — settings;
  - — music;
  - — repeated images/phrases/actions/symbols/ideas;
  - — changes in lighting;
  - — changes in audio volume;
  - — background sights and sounds; and
  - — camera angles.



- Incorporate these observations into notes and generate questions about their significance.
- Include references to the lecture/text and other material as they come to mind.
- Write a summary of the content of the video or speech.
- Write a reflection about the content of the material. What was the point of view? How did the material make you think?

Tips on Taking Discussion Notes

Incorporate Discussion Topics/Questions

- Use the topics and questions posed by discussion leaders to guide the content of the notes.
- Use symbols to indicate questions and ideas that seem to carry weight or significance, and consider the discussion leader's purpose in emphasizing them.
- Incorporate a variety of responses into notes; consider and react to the various responses during review of notes.
- Generate questions to inject into the discussion or review later with other students, tutors, or teachers.
- Incorporate references to the lecture, text, and other material as they come to mind.

Tips for Studying with Notes

Make Use of the Format of Your Notes

- Spread out or hold your Cornell-style notes so that the right-hand side of the page is covered; review ideas and answer study questions from the left-hand column; use the right-hand specifics as answer key.
- Engage in oral quiz with others using study questions from the left-hand column.

Write

- Write summaries of the most important material in the summary/reflection section.
- Write anticipated test questions beyond those already in the left-hand column and write answers to the questions.

Review

- Look over notes frequently to keep information and questions still unanswered fresh in mind.
- Recite information from notes.
- Rewrite notes if necessary.
- Answer all the questions you developed in your Cornell notes and then check that you are correct.

Study With a Group

- Exchange notes with others to flesh out information and understanding.
- Use notes in study groups to provide common ground of material for reference and review.
- Write questions that the instructor might ask and answer those questions.

Concept Mapping

Timeline

50 minutes initially. *Allow 10 minutes to discuss why and how the use of concept maps will enhance student learning and to go through a sample demonstration. Students then work in groups to create a collaborative concept map and report out (40 minutes).*

WIC-R Strategies

- Writing
- Inquiry
- Collaboration.

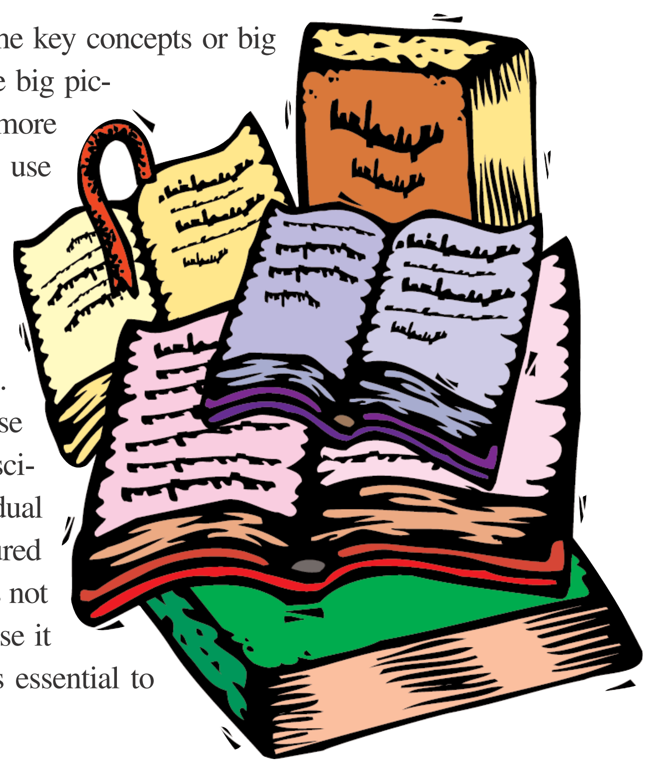
Materials

- CD (Power Point)
- Student Handout ("The User's Guide to Concept Mapping")
- Overhead Transparency ("Sample Concept Map on the Nature of Science")

Concept Statement

Concept mapping is a technique for representing the structure of information visually. The concept mapping technique was developed by Joseph D. Novak at Cornell University in the 1960s. His work was based on the theories of David Ausubel, who stressed the importance of prior knowledge in being able to learn about new concepts. Novak concluded that *"Meaningful learning involves the assimilation of new concepts and propositions into existing cognitive structures."* Students are able to use this method to link cognitive schema into visual patterns and to solidify their conceptual learning.

As teachers we understand the importance of linking the key concepts or big ideas in science. We understand that being able to 'see' the big picture helps student access difficult information and fit it into more manageable bundles. Even though we, as science teachers, use analogies and metaphors to help our students 'get it,' if students are given the tools to construct their own meaning maps as well as incorporate essential vocabulary, they are much more likely to hold on to the central concepts and more deeply understand the relationships between them. One of the best ways for students to cognitively make these mental maps is to regularly create concept maps about the scientific content they are studying. These maps are as individual as your students, but great value can be gained from structured collaboration and concept map sharing. Concept mapping is not a passive activity, but one that requires mental effort because it cannot be done without analysis and synthesis—processes essential to critical thinking.



 Teacher Guidelines (2 of 2)

Lesson Plan

1. Distribute the student handout "The User's Guide to Concept Mapping." Assign students to read it prior to doing this lesson. Preview the "How to Concept Map" Power Point presentation on the companion CD.
2. Explain how the use of concept maps helps students learn in a visually graphic way, which is highly effective and solidifies understanding.
3. Use the overhead transparency ("Sample Concept Map on the Nature of Science") to show the various linkages and how the map is organized.
4. Have students work in groups of three using their Cornell notes (and optionally textbook) to make a collaborative concept map on the last unit of study. They should have some shared knowledge about this topic. Give students pieces of poster paper (or butcher paper) felt-tip markers (water-based are best), and a time limit (35 minutes). You may want to list vocabulary they must include in their maps on the board.
5. Have students work in groups. When time is called, have two groups share their maps and explain how they linked the concepts. Alternatively, you can have students post their maps and have other groups score them, using the rubric in the student handout.
6. Clarify any questions. Refer to the concept mapping rubric and discuss.

References

Novak, J. D. (1991). Clarify with concept maps: A tool for students and teachers alike. *The Science Teacher, 58*(7), 45–49.

Novak, J. D. (1993). How do we learn our lesson?: Taking students through the process. *The Science Teacher, 60*(3), 50–55.

Ross, B. & Munby, H. (1991). Concept mapping and misconceptions: A study of high-school students' understanding of acids and bases. *International Journal of Science Education, 13*(1), 11–24. (EJ 442 063)

The User's Guide to Concept Mapping

Reading assignments are as important to the work in science classes as labs and problems are. I expect you to read the assignments and mentally address each of the questions that are posed throughout the reading to check your understanding. There are several uses for source materials (articles, textbooks, etc.) in science classes:

1. To reinforce information covered in class;
2. To provide more in-depth coverage of material;
3. To preview upcoming material; and
4. To show alternate ways to solve problems.

In order to make sure that you are completing the reading assignments and to provide you an easy way to review for tests and the final, you will create a concept map (or maps) for assigned readings. Good concept maps are useful as review tools or quick reference tools when you encounter new material that depends upon past material.

A concept map is a way to organize learning in which you extract the most important ideas from the reading and relate them in a meaningful way on a "map." Each map will be unique and will reflect your individual style. Common to all maps will be the central topic (expressed in one or two words) written in the very center of the paper. All other ideas are clustered around this central idea. *The central idea should NOT necessarily be the same as the title of the reading.* Each map should be kept to a page. If there are too many ideas to incorporate on one page, the map needs to be divided into two or three smaller, more manageable maps.

The central concept branches out in several directions showing all relationships through linking phrases and arrows. Ideas that support the main concept are closer to the center than other ideas that are less related. Important terminology is linked to the appropriate ideas in clear, explicit phrases. Specific examples that clarify concepts and illustrate ideas are important to concept maps. Beware!! Concept maps do *NOT* use complete sentences. The idea is to highlight the important ideas, not dwell on vaguely related concepts or unimportant trivia. Pictures and other graphics are a great addition. Graphs may be the most simple format for displaying a concept. To accent certain ideas (e.g., the formulas), utilizing different colors of ink is a must. Using one color to show vocabulary, another for formulas, another for defining characteristics, etc. would help set off these different parts of the concepts at a glance.

Concept Map Quality

Superior concept maps represent the major concepts concisely. There are not too many ideas as to lose the main point, but there are enough ideas to paint a clear picture of this concept and the relationships of the subordinate ideas. The linkages between concepts are clearly defined with arrows and precise phrases. An organized plan is evident rather than a rambling, random path through the reading. This organization needs to arrange the concepts around the central idea instead of a linear path.

Concept Map Features Review

One central idea per map	Does not use complete sentences
No larger than one page (8.5 x 11) per section	Uses different colors of ink keyed to concepts
Includes linking phrases and arrows (looking for relationships)	Includes graphics when appropriate
Includes important terminology, does not focus on unrelated/vague ideas	Uses explicit clear language to expand concepts
Includes "sub-concepts" in separate bubbles and has specific examples	Includes a section on units (when appropriate for topic, e.g., metrics, formulas)
Flows vertically *and* horizontally (not just linear—links connect both vertically and horizontally, too)	Includes a section with mathematical formulas and applications/when to use each. When appropriate for topic, e.g., metrics, formulas

Reading Tips for Concept Mappers

- Each chapter is organized into sections. Before you read, you should preview the chapter using these section headings to give you an idea of what is about to be read.
- Ask questions about what you expect to read before you read the assignment.
- Determine what you know about the topic prior to reading the assignment. It is much easier to add to existing knowledge rather than to start with a blank slate.
- Use the questions in the reading, or generate your own, to quiz yourself about the concepts you just read.
- Review the material in short bursts and review often. The more times you study material, the longer you retain the information.

Concept-Mapping Rubric - Basic Elements Defined

1. **Number of concepts**. Tends to have too few or too many concepts vs. only the major concepts.
2. **Linkage Validity**. Inaccurate linkages between concepts vs. accurate linkages.
3. **Linkage Quality**. Few or missing/linkages and vague linking phrases vs. important linkages and explicit and clarifying linking phrases.
4. **Horizontal vs. Vertical Flow**. Tends to flow in one direction vs. even radiation from central core.
5. **Specific Examples Expand Concepts**. Uses specific examples to show understanding of the concept vs. unrelated or vague examples.
6. **Formulas and Units**. States appropriate formulas, defines important units, includes application for equation.

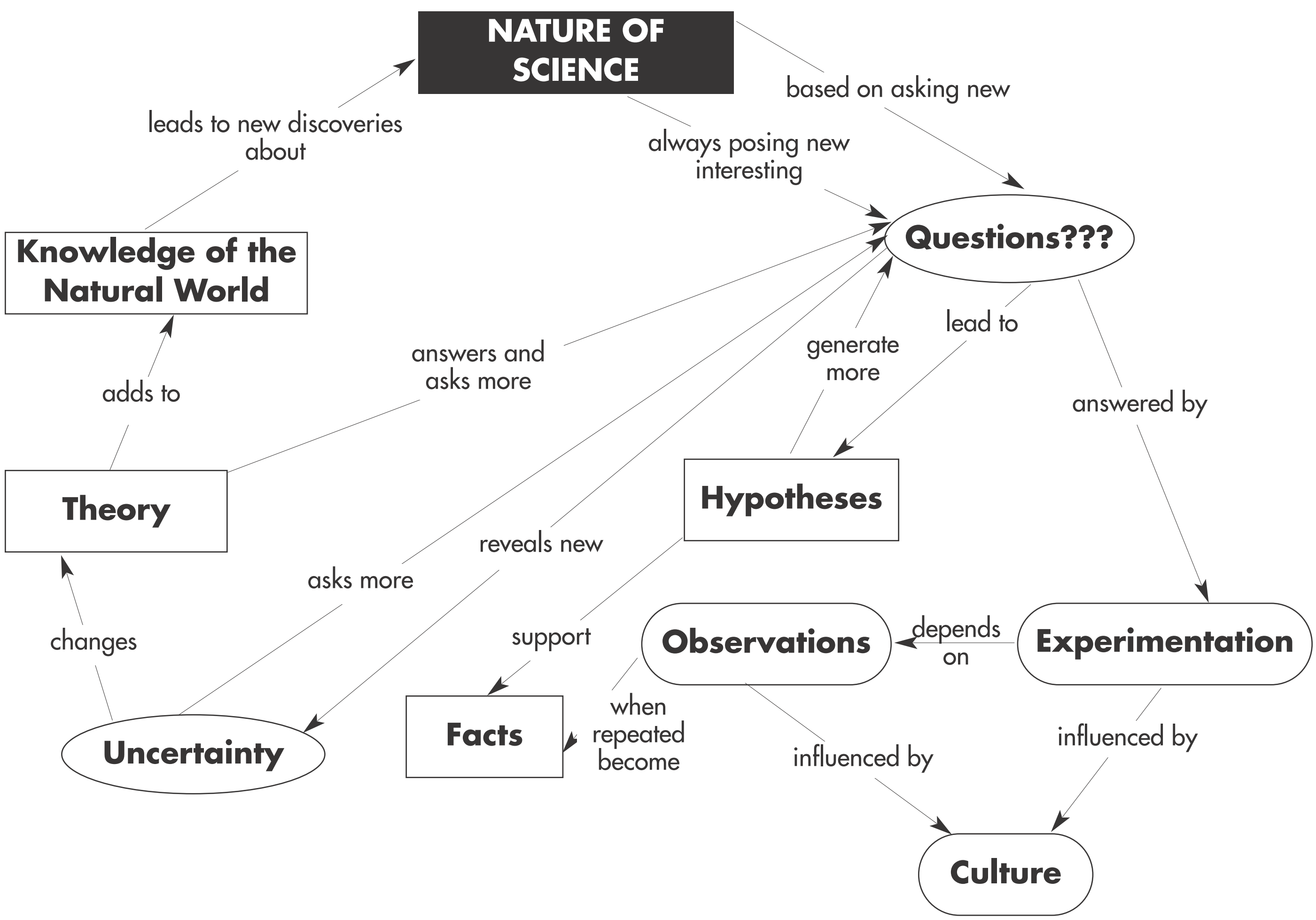
Performance Standards for Student Work

Quality	Level	Description of Standard
Superior	4	Fully achieves the purpose of the task, while insightfully interpreting, extending beyond the task, or raising provocative questions. Demonstrates in-depth understanding of concepts and content; uses dynamic and diverse means.
Good	3	Accomplishes the purpose of the task. Displays understanding of major concepts even though less important ideas may be missing.
Fair	2	Purpose of the task is not fully achieved; needs elaboration; assumptions are flawed. Gaps are evident; fragmented understanding of concepts.
Poor	1	Purpose of the task is not accomplished; shows little evidence of appropriate reasoning; does not successfully communicate relevant ideas; presents extraneous information.

Rubric Grading Criteria

	Poor	Fair	Good	Superior
Number of Concepts	1	2	3	4
Linkage Validity	1	2	3	4
Linkage Quality	1	2	3	4
Flow	1	2	3	4
Specific Examples	1	2	3	4
Formulas and Units	1	2	3	4

Sample Concept Map on the Nature of Science



UNIT 2: WRITING TO LEARN IN SCIENCE

***"Humans were born to think; it's almost impossible to stop us. Writing helps us to bring all that activity into consciousness, helps to clarify and direct our thinking, and generate more thinking."* —Catherine Copley (1995). The Writer's Complex**

Overview

Goal: **To help students to use writing as a thinking tool and to learn how to analyze and write to complex prompts.**

Many science teachers do not consider themselves writing teachers—that job, many feel, belongs to the English Department. However, if students are expected to write scientifically, then it falls to science teachers to actively teach students how to write in science. All science professionals write. In fact, they write frequently. They produce formal writing like experimental reports, journal articles, research proposals, monographs, and books, as well as more personal writing in the form of lab notes, e-mail communications, research notes and 'back of the napkin' jottings of ideas and hypotheses. Without some formalized instruction and student practice, students will be less able to write to the complex prompts provided yearly by the College Board and they will not get the opportunity to explore their own learning.

One of the best ways for a student to understand a topic is to write about it. All writing requires thinking. How do I know what I think until I see what I write? There are two basic types of writing used in schools: writing-to-learn and writing for communication (Young, 1999). Writing that is used to process information and build stronger connections between ideas is called "writing to learn" and is often not graded. The second type of writing is used to explain your ideas to the reader. More often than not, this form of writing is the type that is evaluated in classrooms. However, many students do not understand that there is a difference between the two or sometimes even that there are many different uses for writing. Students who think this way often use communicative writing to begin developing their own thoughts in their first (and often only) draft of scientific pieces. They cannot express ideas clearly and concisely because they have yet to understand what they are trying to relay to the reader.

Science teachers can help students negotiate these distinct types of writing and give students relevant support and practice while focusing on science topics. Fostering writing to learn will not take away from teaching content, but will help students develop writing skills as they become more proficient readers and writers.

The Classroom Uses of Writing

Writing is a valuable tool for learning as well as for communication. Based on this premise, teachers trying to help students to prepare for rigorous classes operate with two writing agendas in the pre-AP and AP classroom:

1. Designing certain writing assignments primarily to help students **learn** the scientific material.

2. Using formal writing assignments to help students **communicate** what they have learned to others.

In science classes, students should be expected to both understand the different uses and demands of these two types of writing as well as produce both types of writing. By making this distinction between writing styles, teachers can begin to design some writing assignments to primarily help students learn the material and other writing assignments to help them communicate what they have learned to others (Young, 1999).

Therefore, these two purposes then serves as a guide for instruction planning and the assessment of student work. In instruction, we now have purpose in the types of writing that we require of students. During a class period, we must decide how best to help students to write to learn as well as to communicate their learning. Then use each tool appropriately to offer students the practice that is required to succeed in at high levels AP courses. The increased use of writing in the classroom naturally leads us to read and respond to student work based on the different roles most teachers play: teacher as mentor and teacher as judge.

In order for students to comprehend and absorb complex scientific material, they need an opportunity to process and manipulate the information. Writing about the learning provides an essential way for students to master difficult information. Such writing-to-learn activities give teachers a structure for assigning ungraded writing regularly (but checked and required), thereby compelling students to practice this skill. These assignments encourage students to formulate ideas, develop their understanding of scientific principles and learn through the medium of writing. The Interactive Notebook discussed in Unit 1 provides an organizational framework via a place for students to regularly complete this type of writing. Writing-to-learn activities also help students learn to effectively

WRITING AND THINKING

Characteristics of Writing-to-Learn	**Characteristics of Writing to Communicate**
• Teacher is a mentor	• Teacher is an evaluator
• Discovery Thinking for yourself	• Critical thinking, ideas, findings to others
• Uses informal style that makes sense to author	• Uses formal academic language
• Used to clarify the author's thinking	• Write carefully for specific readers
• Forms: Journals, Notes, Rough Drafts	• Forms: Essays, Lab Reports, AP Exams

Adapted from *Teaching Writing Across the Curriculum* (3rd Ed.), Art Young, 1999. Prentice Hall, N.J.

manage and use information to solve problems, to interrelate knowledge, and to construct understanding. As a result, students build mental fluency through repeated opportunities to write and to share their ideas with others.

Thomas Edison provides a good example the scientist as a writer; he filled hundreds of pages a week in his small pocket-sized notebooks. Here is a brief section from an entry in his Greenwich Cable Telegraph Pocket Notebook of June 10, 1873:

> *....ascertain if some magnetic arrangement might not be made so as to be included with the circuit [&+w] so that it would exactly neutralize the static charge in So many knots of Cable if these devices Could be put in the Cable & their Capacity would remain as Constant as the Capacity of the Cable = it would be valuable = T r y t W O k E + & & d disks of rubber on which is a strip of Zinc & of Copper Connected together*

= This stands still now another disk 100th of an inch from it revolves slowly & also with immense rapidity This disk has one Strip Copper. See if influence would generate E. & Connect to Sensitive Galvanometer = (The Papers of Thomas A. Edison, vol. 1, ed. Reese V. Jenkins et al. [Johns Hopkins University Press, 1989], p. 613).

* More of Edison's original documents can be found at http://edison.rutgers.edu/.

Teachers, especially AP teachers, often only use writing as a way of testing or evaluating students. By using writing to assess what students already know, rather than as a way of encouraging them to learn, we deprive students of the chance to change and modify their schema. Writing as a learning tool promotes not only student interaction with curriculum ideas but also engages students in active learning processes like researching information, compiling notes, evaluating validity, analyzing data, organizing content, annotating personal reflection, and selecting words precisely to construct clear meaning. The direct result of knowledgeable application of these process skills is the clear expression of complex ideas or better writing as communication. Simultaneously, students are better prepared academically for any challenging course because the valuable skills learned through *writing-to-learn* and subsequent *writing as communication* translate across all disciplines in all learning environments.

The following unit highlights both types of writing assignments. We will begin with information and activities for *Writing-to-Learn.* Next, we introduce activities and strategies to help students to master scientific vocabulary, an essential skill for new knowledge acquisition. Finally, we will examine specific information and exercises concerning how to prepare students for timed writing prompts and ways to use evaluations so that students also learn from these rigorous assessments.

Tips for Designing Writing-to-Learn Assignments

1. Writing-to-Learn activities fulfill the following goals:
   - To deepen understanding, not to fill time with busy-work.
   - To engage students in interactive learning situations.
   - To foster high-quality classroom discussions.
   - To connect science content from lecture with the reading, labs and other class activities.
2. In designing writing prompts to facilitate student learning there are several questions to ask.
   - *How will this assignment promote knowledge, develop critical thinking and/or communication skills?*

     For an effective prompt, students must not simply regurgitate factual information. Instead they must invoke higher level thinking skills. They must analyze, synthesize, and apply. They must build a scaffold of understanding based in fact but extended beyond the facts. Some key words to use in writing these prompts are: predict, what if, evaluate, apply, diagram, compose, compare/contrast/categorize, sequence, consider, criticize and explain (from Costa's levels of questions). These types of key words help students apply recalled information, thereby processing it, to build deeper connections between ideas and strengthening learning.
   - *How will I "count" or grade these writings, if at all?*

     We all know that students don't do what you don't "grade." You must devise a way that makes this writing important to the student. Some suggestions are checking them as homework on a complete/not complete basis, reading them in pairs in class and having students constructively criticize each other's work, or writing these prompts in the Interactive Notebook where they are part of a graded assignment but do not require reading (only skimming) by the teacher and are therefore graded for completion but not content.
   - *How does this assignment relate to other work and purpose of the class?*

     Everything done in a classroom should have a purpose. Consider how the writing-to-learn that you use enriches students' experience and furthers their learning. Does the writing help them to remember a complex process? Will creating a poem help you remember the major steps of the Kreb's cycle, or will it help them compare two types of problems or situations? For example, will drawing a flow chart help students explain the critical differences between finding the pH of a strong acid titrated with a strong base versus a weak acid titrated with a strong base? While both examples are writing-to-learn, the purposes differ. One would work to help students remember a series of steps and the other would help students to grasp the similarities and differences in titration problems.

Sample Writing-to-Learn Activities

1. Quick Writing

Quick Writing is probably the easiest to introduce and have students do. Basically, quick writing is simply writing down everything that comes to mind on an assigned topic, usually for five or ten minutes without stopping. This type of writing is informal and unedited. It is reflective and questioning with the point of discovering what you do and don't know. It is usually written in class and develops writing fluency. It does not have to be read by the teacher.

2. One Minute Essay

The one-minute essay can be used at any time during a class, but are frequently used as a closure activity. Students turn them in on their way out the door. At the end of class, the teacher asks students to write for a minute (or three or four) about two things:

a. What they learned in class today and

b. What questions or confusions they still have.

Students are able to quickly review what they do and don't know and then get help.

Teachers can then scan the 'essays' and find out where students are stuck. Sometimes students will not want to ask questions in front of a class, but they will put them on paper. If students know they will be expected to produce a summary of the work, they are more likely to be engaged during class. You can experiment with ways to handle the paper:

- Look over the papers and summarize the main questions for everyone.
- Don't collect the papers (have students use their InterActive Notebooks) and ask three or four students to read what they wrote the day before.
- Put students in groups of four and have them read and respond to each other's questions.

3. InterActive Notebook

The best place for students to frequently use for *writing-to-learn* assignments (on the left pages) as introduced in detail in Unit 1. Grading is holistic and allows students to do writing which they keep in chronological order and is not scattered on loose papers.

4. Science Notes

Several times during a unit, students write a 100 word minimum "note" to another student summarizing what they understood about the concept being studied at that time and describing the difficulties and questions they have. Students then exchange notes and respond to each other by the next class (or as assigned). A copy of the response goes to the teacher. This is recommended for topic areas that you know students usually have trouble learning (Thermodynamics, Kreb's cycle, etc).

5. A One-Sentence Summary

- *Be sure to model your own one-sentence summary for your students.*
  a. A one-sentence summary covers the **most important** information or the main ideas in the reading or lecture.
  b. Have students write one-sentence summaries about films, labs, lectures, and reading selections.

c. To hone the skill...have students start with a paragraph summary and reduce it to one sentence.

d. Students can create a one-sentence summary using the format below. The blanks are optional.

e. Include one-sentence summaries for comprehension practice. List three or four key vocabulary words and have students write a sentence that connects them.

f. Post the best one-sentence summaries. Then share with all students WHY these summaries work.

Here are some sample open-ended formats to turn into one-sentence summaries.

Description	A ___ is a kind of ___ that.....
Compare & Contrast	_A_ and __B__ are similar in that they both___, but _A_...., while __B_
Sequence	___begins with ...., continues with...., and ends with......
Problem/Solution	___need a 1 molar solution of HCl...., but..., so.....
Cause/Effect	__X__ happens because.....

Additional Resources

1. Sebranek, P., Kemper, D. & Meyer, V. (2001). *Writers INC.* Wilmington, MA: Write Source.

2. Young, A. (1999). *Teaching Writing Across the Curriculum,* (3rd Edition). New York: Prentice Hall.

3. Copley, C. (1995). The Writer's Complex, Empire State College. [Available online: http://www.esc.edu/html-pages/writer/copley/hmpg.htm.]

Science Vocabulary Cards

Timeline

Can be assigned as homework and used in class linked to review or other activities.

Process Skills

Deepen concept understanding by developing vocabulary mastery.

WIC-R Strategies

- Writing
- Inquiry
- Collaboration
- Reading

Materials

- Student Handout ("Science Vocabulary Cards")
- Overhead Transparency ("Sample AP Biology Student Vocabulary Card")

Concept Statement

Pre-AP and AP science students are often challenged with the amount of unfamiliar vocabulary. However, without a strong foundation in the vocabulary of science, they will not be able to master the complex concepts of scientific content. The words they learn become stepping-stones to the next concept—and without those words, the large potholes slow down their progress resulting in frustration. There is a strong connection between reading comprehension and vocabulary development. "Teaching words well means giving students multiple opportunities to learn how words are conceptually related to one another in the material they are studying" (Vacca & Vacca, 2002, p. 160). These activities should become a foundation to increasing reading comprehension and are intended to link closely to teaching the content. The following vocabulary activities are designed to help students acquire scientific vocabulary, the underlying concepts and to make it their own.

Lesson Plan

These activities are best used frequently. Students need to constantly add to their science-specific functional vocabulary.

1. Pick out 8–12 essential "must know" vocabulary words for the chapter or unit you are studying.
2. Distribute Student Handout "Science Vocabulary Cards."
3. Review the requirements and grading rubric with students.
4. Use overhead transparency to show a model of a student Science Vocabulary Card or create your own.
5. Have students independently create Science Vocabulary Cards for the assigned words, or work in teams to create the set.
6. Students may post their cards in the room, or create their own set of flash cards for review.
7. Have students, individually or in small groups, arrange the vocabulary words into a concept map with the linking connections as review for the end of unit exam.
8. Check the student vocabulary cards using the rubric, or have the students check each other's, using the same rubric. Student understanding of the words can be assessed by having them construct a concept map using the words (See Unit 1 for specifics on concept maps).

Resources

Vacca, R. & Vacca J. (2002). *Content area reading.* Boston: Allyn and Bacon.

Science Vocabulary Cards

Purpose

To help you learn scientific vocabulary and the concepts that go with them.

Vital Card Statistics

- **Word** (spelled correctly)
- **Pronunciation** (nice, but optional)
- **Definition:** meaning of the word using terms that you understand (the glossary or dictionary definition might not be the best source).
- **Link:** A word that is useful in remembering the target word. You should know the meaning of the link word. It can relate to or rhyme with the new vocabulary word.
- **Visual:** A sketch or drawing that creates a clear picture of the word meaning. It includes a short sentence including the new word and the linking word.
- **Usage sentences:** Two sentences that help practice the word. (1) Uses the word in context from the text (give page number.) (2) Your own sentence applying the word showing your scientific knowledge.

VOCABULARY CARD GRADING RUBRIC

Card written in ink on 4 x 6 card or notebook page	
Front: Word clearly written in large printed letters	
Link word identified on front of card	
Drawing or sketch of word drawn	
Link word in sentence under drawing **Back:** Definition clearly written on back of card in your words	
Sentence #1 below definition uses word in context (text w/pg #)	
Sentence #2 below definition student uses own sentence (showing you understand the meaning)	
TOTAL	

Revision Required *Well Done*

0 1 2 3 4

SAMPLE AP BIOLOGY STUDENT VOCABULARY CARD

CARD FRONT

Pleiotropy

(Plee-o-tropy)

Link = Drugs

Pleiotropy is like a drug; it influences traits. Drugs can influence in negative or positive ways, depending on how you use them.

CARD BACK

When the alleles at one gene location affects an organism in multiple ways and can cause positive or negative effects.

1. Pleiotropic alleles responsible for certain hereditary diseases in humans cause multiple symptoms (p. 258).

2. Sickle-cell anemia is a good example of pleiotropic effects, it gives resistance to malaria, but it causes death at a young age.

Four Square Analogy

Timeline

Assign as homework or use in class. Use as a quickwrite in class, plan on approximately 8–10 minutes to write, and 5 minutes to debrief or partner share.

WIC-R Strategies

- Writing
- Inquiry
- Collaboration
- Reading

Materials

- Student Handout ("Four Square Analogy")

Concept Statement

Pre-AP and AP science students are often challenged with the amount of unfamiliar vocabulary. However, without a strong foundation in the vocabulary of science, they will not be able to master the complex concepts of scientific content. By giving students opportunities to construct their own analogies related to the content, students can use their own experiences and schema to develop unique and lasting understandings of the words and concepts. The benefit of using the Four Square Analogy is that you can also use it for processes as well as vocabulary words. This also lends itself well to an InterActive Notebook activity for writing to learn.

Lesson Plan

These activities are best used frequently. Students need to constantly add to their science-specific functional vocabulary.

1. Pick an appropriate word or process for the Four Square Analogy activity.
2. Distribute Student Handout "Four Square Analogy."
3. Model the activity on the overhead or board, using a sample word of your choice (for example 'cell'). Ask students to suggest items to put in the boxes.
4. Give students the target word or process (or have them choose from several) and have them fill out the sheet individually as homework or in class.
5. Have students pair-share their analogies and give each other feedback. Call on a few individuals or ask for volunteers to share with the class.
6. To assess this writing-to-learn activity, check for participation and completeness. Students will have a wide variety of responses and with practice will be able to create their own analogies without prompting.

FOUR SQUARE ANALOGY

1. Write as much information as you can about: ______________________	2. ______________________ is like ______________________ because:
3. Describe what it would be like to be ______________________	4. What are some important characteristics of ______________________?

Tackling AP and Other Essay Prompts

Timeline

30 minutes to teach the strategy and another 20 minutes of practice.

WIC-R Strategies

- Writing
- Inquiry
- Reading

Concept Statement

Pre-AP and AP science students are often challenged by having a short amount of time to write to a detailed multi-level essay prompt. It is easy to skip over areas of the prompt or to lack a strategy to meet this challenge. Students can be taught how to attack complex prompts and to make sure they apply the content knowledge in a coherent way. By using this technique with your own test questions and having students practice the technique, they can improve their ability to write under these stressful conditions. In this activity an essay is a prompt that requires anywhere from a few sentences to many paragraphs. On the AP exams, the life/environmental sciences are usually prone to the latter while the physical sciences more easily tend to the former.

Lesson Plan

Students should have to answer essay test questions with every unit. They can use this method with every essay test.

1. After the first unit test, have students reflect on how they organized their response to essay prompts. Share some model responses.
2. Distribute Student Handout ("Timed Writing for AP Science").
3. Using the overhead transparency "Timed Writing for Science Students," review strategy for Attacking the Sample Prompt (adapted from an AP Biology test questions from 2002, and available on-line from the College Board).
4. Have students take the prompt from their first test and use the A-T-P technique to attack it.
5. Give students another prompt from a former AP test and have them 'attack' it in groups. Have students reflect on how they might use this strategy on the next test.

   Former AP test questions and descriptions of the scoring guides are available from AP Central http://apcentral.collegeboard.com/. You will need to register as a teacher on the website, and will then have access to the most recent information on testing, rubrics, and other useful information.
6. **Assessment:** Student essay writing should improve in answering all parts of the prompt and in organization of their responses.

Timed Writing Strategy for Science Students

A-T-P (Attack the Prompt)

Attack the Prompt—You must answer all parts of it!

- Underline "to do" and action words—these tell you what's required.
- Sort the question into it's distinct parts or sections.

For example: (When looking at a given graph of a species' biorhythms)

a. **Describe** the cycle of activity for the organisms. **Discuss** how the following factors might affect the behavior of the organisms to result in this pattern of activity.
   - food
   - predators
   - temperature

b. **Propose** a hypothesis regarding the effect of light on the cycle of activity in the organism. **Describe** a controlled experiment that could be performed to test this hypothesis, and the results you would expect.

TO DO WORD	**TASK** (Sort the question into its parts)
Describe	The cycle of activity for the organisms
Discuss	How [food, predators, temperature] each affect behavior that matches the graph.
Propose	A hypothesis about the effect of light on activity
Describe	A controlled experiment to test the hypothesis
Describe	The results you would expect from the experiment

Target possible answers

- Map or cluster brief details under each specific prompt area.
- List specific information or examples under each.
- Use key vocabulary words from your content knowledge.

Pick the order of your response

- Arrange your map/cluster/outline into sections or paragraphs.
- Begin with answering the prompt immediately—don't write introductory. statements or restate the prompt, this just wastes time and earns you zero points.
- Don't forget to use key vocabulary words and describe processes in detail.
- Go back and make sure you've answered all parts of the prompt—major points are lost when you skip a portion of the prompt.

Timed Writing for AP Science

How to Answer Essay Prompts

Answering long timed essay PROMPTS that are worth many points requires more sophisticated writing skills. In a long answer, you will include a great deal of concise information and most of it should be specific, not vague or generalized. Successful students write precise essays and make sure that everything said is relevant to the prompt and that all parts of the prompt are answered completely. For this you need two main abilities: to be able to detect the key words in the prompt, and to know how to quickly organize your ideas. Here are some crucial direction words used in essay exams.

See if you can write a quick definition for each word. Then compare your answers with the definitions that follow.

1. COMPARE
2. CONTRAST
3. DEFINE
4. DESCRIBE
5. DISCUSS
6. ENUMERATE
7. EVALUATE
8. EXPLAIN
9. INTERPRET
10. PROVE OR SHOW
11. ANALYZE

Here are examples to compare with yours. An understanding of these words will permit you to control what you say. To write an effective essay you must apply your knowledge to the questions and stick to the point. It isn't enough just to write down everything you know.

1. **Compare:** show the similarities between two events, periods, ideas, theories, or the like. (Some teachers use COMPARE to mean showing differences as well as similarities, so be careful.) *Example:* compare sexual reproduction in plants and animals.
2. **Contrast:** show the differences between two or more events, periods, ideas, theories, or the like. *Example:* contrast the functions of chloroplasts and mitochondria.
3. **Define:** state the meaning of a word or phrase. *Example:* define chemiosmosis.
4. **Describe:** give the characteristics of something. *Example:* describe the functions of the ATP/ADP systems.
5. **Discuss:** give the specific details or 'how' on an issue, event, process, theory, or technique. *Example:* discuss how the polymerase chain reaction replicates DNA.
6. **Enumerate:** list a number of reasons or attributes of something. *Example:* enumerate the stages of protein synthesis from RNA to a finished protein.
7. **Evaluate:** make a judgment or give an opinion, or supply reasons why something is as it is. *Example:* evaluate the effects of Jenner's experiments with cowpox.
8. **Explain:** support or qualify a given generalization with specific facts and ideas. *Example:* explain what is meant by the "scientific method."
9. **Interpret:** analyze critically or explain the relationship clearly. *Example:* graph and interpret the following data on mitosis rates of two onion species.
10. **Prove or Show:** demonstrate the truth or a statement, explain the reasons for events turning out as they did, or speculate on what might be the effects of certain causes. *Example:* show with diagrams and descriptions how the eye is like a camera.
11. **Analyze:** break the whole into its key elements and comment on the relationship between the parts. *Example:* analyze the function of the DNA molecule in prokaryotes as compared to eukaryotes.

A-T-P (Attack the Prompt)

Attack the Prompt—You must answer all parts of it!

- Underline "to do" and action words—these tell you what's required.
- Sort the question into its distinct parts or sections.

For example: (When looking at a given graph of a species' biorhythms…)

a. **Describe** the cycle of activity for the organisms. **Discuss** how the following factors might affect the behavior of the organisms to result in this pattern of activity.
   - food
   - predators
   - temperature

b. **Propose** a hypothesis regarding the effect of light on the cycle of activity in the organism. **Describe** a controlled experiment that could be performed to test this hypothesis, and the results you would expect.

TO DO WORD	TASK (Sort the question into its parts)

Target possible answers

- Map or cluster brief details under each specific prompt area.
- List specific information or examples under each.
- Use key vocabulary words from your content knowledge.

Pick the order of your response

- Arrange your map/cluster/outline into sections or paragraphs.
- Begin with answering the prompt immediately—don't write introductory. statements or restate the prompt, this just wastes time and earns you zero points.
- Don't forget to use key vocabulary words and describe processes in detail.
- Go back and make sure you've answered all parts of the prompt—major points are lost when you skip a portion of the prompt.

UNIT 3: READING TO LEARN IN SCIENCE

Overview

When students get to college, they are expected to learn through two primary channels: listening to lectures and reading text. These are often the two ways students are expected to learn in Advanced Placement courses, as well. Unfortunately, the skills required for reading to learn in rigorous coursework are not consistently taught or reinforced. This unit focuses on activities intended to help students improve their reading-to-learn skills.

According to recent research, reading comprehension strategies are not directly taught past sixth grade. It's up to the content area teachers to help our students read our content. "The most logical place for instruction in most reading and thinking strategies is in social studies and science rather than in separate lessons about reading. The reason is that the strategies are useful mainly when the student is grappling with important but unfamiliar content" (*Becoming a Nation of Readers,* 1985).

From a strategic point of view, the reader's main goal is to make sense of what is read. The teacher's main goal is to clear up confusion by teaching students how think strategically by:

- having students use prior knowledge.
- encouraging student questions about the text.
- modeling how to reject, modify or confirm educated predictions about text.
- giving students opportunities to practice comprehension development as part of the content learning.

Good readers first survey the type of medium they are reading. Journal reading requires different skills than reading textbooks. Because AP courses are often dependent on textbooks for information, the first activity, "Introducing the Text," helps students to identify the main components of the book from the foreword to the glossary. Having students complete this activity may also provide information about their level of textbook reading skills.

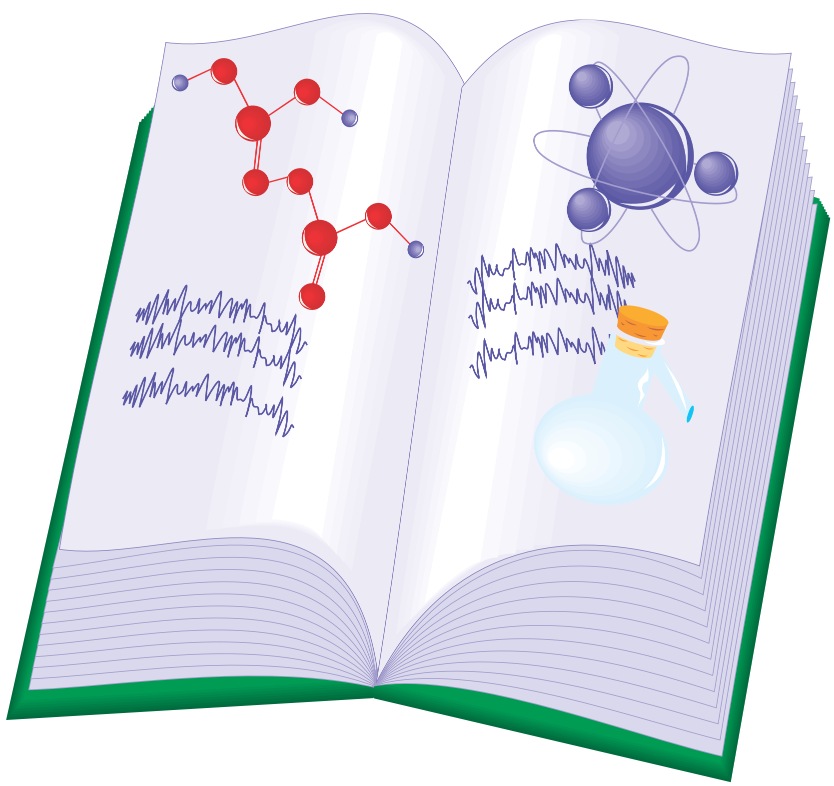
"Dissecting the Text" uses tested reading strategies to engage students in reading. Required to underline, highlight and question in this activity, students must interact with the text physically, thus process information.

"Active Reading Strategies" provide a variety of ways in which students can work with the text to construct meaning and develop a deeper understanding. This activity requires students to demonstrate what they already know in creative ways.

"Get Curious" demands that students ask questions about the text rather than seeking out the answers to prepared questions used to make sure students read. When students must respond to open-ended prompts such as these, they gather more information rather than answering questions like "Who were the astronauts on the Apollo 13 mission and what were their jobs?" The reading-writing combination helps students to formulate an understanding of the material.

Finally, "Having a Conversation" provides students with a framework for an internal dialogue that good readers use. By invoking graphic organizers to represent the student's *schema*, this activity helps students to juggle lots of factual information into a cohesive picture. Additionally, this activity begins to help students to see that not all texts are written clearly with an organization that is self-evident to a reader. Good readers must work to understand the organization and then read to learn.

The following student activities direct students to consciously work on developing their reading skills. These activities can be reproduced and given to students for both on-going instruction and reference during the year.



Introducing the Text

Timeline

Varies from 20–30 minutes, depending on the complexity of textbook

WIC-R Strategies

- Writing
- Inquiry
- Reading

Concept Statement

Most students attack a text by reading only the information assigned. There is little emphasis placed on reviewing diagrams, pictures, charts and graphs. Pre-reading strategies are critical for understanding science texts. In this activity, students familiarize themselves with key parts of science textbooks and practice skimming chapters by locating the bold subtitles, graphs and other text structural cues. These pre-reading skills help prepare students for the massive amounts of reading that is assigned in college prep level classes.

Lesson Plan

This lesson is best used at the start of the year to introduce students to their textbook. The last question can be revisited before starting a new chapter.

1. Choose a chapter for students to skim. This might be the first chapter for ease of transition or one meatier in science content. Photocopy handout for students.
2. Have students use their text to answer the questions.
3. Provide two words found in the glossary for students to look up. Depending on your students, choose one easy word and one that is more difficult.
4. Have students discuss and refine their answers in a group or with the class.
5. For grading purposes, you may choose to give this as a credit/no credit assignment, read each answer for completeness or stamp for completeness and have students place in their InterActive Notebooks near the front for reference later in the year.

Introducing the Text

Name of Subject: ____

Title of Text: ____

Author(s): ____

Author(s) Qualifications: ____

Copyright date: ____

1. **Prefaces, Forewords** and **Introductions** contain a lot of the same information. These sections give author(s) a chance to talk about why they wrote the book and how they organized it. Read these sections of your book. Explain what you learned about the book from these sections.

2. The **Table of Contents** is like a road map of the book. On what pages are **Table of Contents** located? Give an example of how to use the **Table of Contents.**

3. The **Glossary** provides definitions of terms used in the textbook. Find the **Glossary**. Look up the two words you teacher has provided. Write the definitions. Explain how your used the **Glossary** to find the definitions of these words.

   ____________________________:

   ____________________________:

4. The **Index** is the fastest way to find a topic. Find the **Index** in your book. List three examples of information you discover in this section.

5. Locate **chapter ___**. Skim the **chapter**. List all the tools in the text that can help you to understand the reading (pictures, diagrams, objectives...). Be specific.

Dissecting Text

Timeline

30–60 minutes depending on length of text. (Each subsequent reading will vary on length based on the text length.)

WIC-R Strategies

- Writing
- Inquiry
- Reading

Concept Statement

While many recent textbooks have improved readability with "considerate" features that help students better comprehend information with more graphics and improved text organization, there are still many textual sources that are considered "inconsiderate" making readability more difficult. Many science text books, unfortunately, fall into this "inconsiderate" text category. The purpose of this activity is to teach students how to generate questions while reading "inconsiderate" texts. Students will be asked to create section markings where appropriate, develop questions that predict the content of the section they have created, and highlight main ideas.

Lesson Plan

1. Duplicate the Student Handout, "Dissecting Text."

2. Provide a copy of a selected reading for each student. Keep in mind the following characteristics.

   a. *Presentation of text:* Students need a clear copy with large margins. The text should be clean and easy to read, (12–14 point font uncrowded). Large margins allow for students' notes and questions. Select text that is content relevant.

   b. *Length:* Short, one-page readings are best to start. As students improve their reading skills, they can tackle longer more challenging assignments.

3. Have students read the Student Handout and have them begin with the "Before You Read" activity. Have students share what questions they think the reading will answer. To debrief this section, come together as a class and ask 5–7 students to share one of their questions. This is a quick way to allow students to validate their ideas as well as hear different ideas.

4. Have students read the selection quickly. Give them a time limit that will challenge about half the students. At this time, it is not as important to read each word, but to concentrate on the main ideas that the article is discussing. Have students list main ideas in the text. Write these on the board.

5. Instruct students that they will now reread the selection. This time they will highlight the main ideas and draw a line across the text when there is a shift in topic. For each line, the student will generate a question that they anticipate will be answered in the next section of text. Give students time to read and dissect the text.

6. Have students trade papers and read the questions that were developed. Students should edit each others work.

Teacher Guidelines (2 of 2)

7. Provide a related reading for students to read and dissect at home or in class another day.

8. There are several options for this assignment. One is that students are given a homework grade that reflects work completed. Another is to have students evaluate each other's work based on the rubric. Finally, you can collect and grade the activity based on rubric.

Rubric: Dissecting Text				
Area	**1**	**2**	**3**	**4**
Title Questions	Questions do not relate to article.	Questions are inadequate showing some relation to text.	Questions (2–3) clearly related to topic.	Questions (4) clearly related to topic of text.
Section Divisions/Questions	Questions do not relate to text section.	Poorly developed questions, lacking strong connection to text	Adequate questions, some connection to text	Well-developed questions, strong connection to text

Dissecting Text

You encounter, on a daily basis, many different types or genres of reading materials including textbooks, newspapers, magazines, books and short stories. Each type has a distinct style of writing and text organization. Textbooks tend to be organized into chapters. Each chapter has several sections with labeled headings and include many charts, graphs and pictures to illustrate the content of the chapter. Short stories are different which, typically, do not have section headings and graphics to help the reader focus on the meaning of the text. In general, long sections of text are more difficult to read than shorter, labeled sections. However, as a student you will need to read and understand a variety of material that may often appear to be "inconsiderate" in text design and organization.

This activity is geared to model some pre-reading strategies designed to help you to read and comprehend difficult and "inconsiderate" text. Specific questioning strategies will help break the text into more manageable reading sections.

Materials

Highlighter, pencil

Before You Read

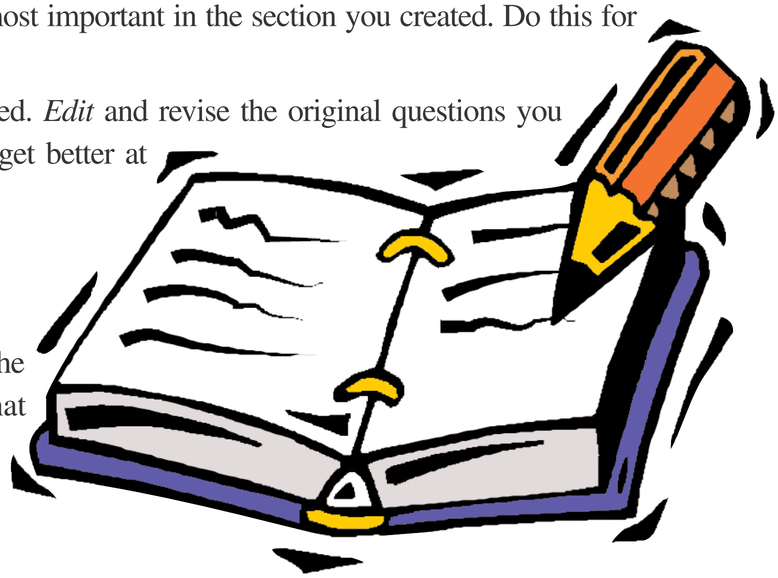
1. Read the title of the reading. On a separate piece of notebook paper, write 4 questions that you would expect to be answered in this reading based on the title. Then predict the answers in short phrases.

While You Read

2. Read the first page of text quickly. Your teacher will give you a time limit.
3. Now read the text at a slower pace. As you read:
   - *draw* a line with your pencil across the text where you think there is a change in topic or idea.
   - in the margin next to the line, *write* a question that you think will be answered in this section.
   - *highlight* the idea that you think is the most important in the section you created. Do this for each section you have marked .
4. Review the section headings, that you created. *Edit* and revise the original questions you developed based on your reading. (As you get better at this, you will need to edit less.)
5. Repeat steps 2–4 for each page of text.

After You Read

6. Review the questions you generated from the title. Draw a line through the questions that were not answered in the reading. Add other questions that were answered.



Active Reading Strategies

Timeline

20–30 minutes including reading time

WIC-R Strategies

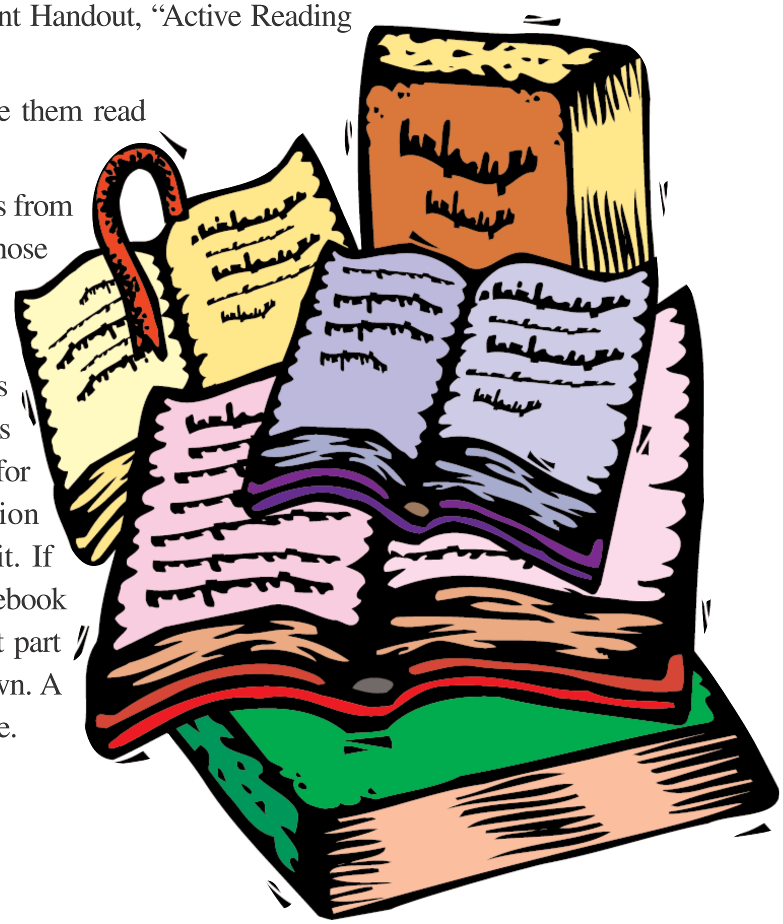
- Writing
- Inquiry
- Reading

Concept Statement

Students all to often read without paying attention. "Active Reading Strategies" is a series of activities designed to engage students in reading by having them participate in small activities as they read the text. We do not suggest all strategies listed for all readings. Be selective and realistic about your students' needs.

Lesson Plan

1. Make an overhead or photocopy the Student Handout, "Active Reading Strategies."
2. Select a reading for students to read. Have them read the section of text.
3. Have students choose two or three strategies from the list provided. They should complete those activities in their notebooks or on a separate piece of paper.
4. The most effective way to hold students accountable for active reading strategies is to assign them as classwork or sometimes for homework. Students can earn participation points or homework checks as you see fit. If you use InterActive Notebooks or have notebook checks, these activities can be a significant part of the whole rather than graded on their own. A simple complete or not complete will suffice.



Active Reading Strategies

Science textbooks are often difficult to read and comprehend. Represented are strategies good readers use to improve learning. Active reading, if used consistently, will help you become an effective and efficient reader.

Procedure

1. Preview the chapter by skimming it.
2. Choose ___ of the following activities to complete.
   - Turn the titles, headings and subheadings into questions.
   - Create new titles, headings and subheadings for each section.
   - Develop questions from reading, pictures or data.
   - Prepare a graph table or chart from the reading.
   - Write a poem about a key term or idea.
   - Provide new examples or make connections to another science topic.
   - Create visual illustrations or drawings about the reading.
   - Evaluate a section of the reading.
   - Develop "what if" statements from the reading, pictures or data.
   - Relate the text to your personal experience.
   - Compose a metaphor or simile.
   - Create an analogy.

Get Curious and Ask Questions

Timeline

20–30 minutes reading time included

WIC-R Strategies

- Writing
- Inquiry
- Reading

Lesson Plan

Science teachers know how important inquiry-based instruction is to the field of science. This activity provides a simple strategy for encouraging students to ask more analytical and inquiry based questions, both in class and while reading.

1. Early in the year, have students brainstorm 10–15 questions from any area of the text that interests them. You can list their questions by category on the board and use them later to reintroduce topics as they come up during the year. The questions can also guide the types of readings that you assign students.

2. Discuss what students already know about the reading topic before the assignment is made. Activating prior knowledge is key in helping students make sense of the current reading assignment.

3. Assign reading.

4. Have students complete a four-square chart as they read (see Student Handout).

5. Let students discuss their responses in a small group or with the class. This gives them a chance to evaluate their critical thinking skills as well as to discuss and review the contents of the reading.

6. Conclude activity with a quickwrite. The four-square responses act as the pre-write idea list.

7. Monitoring group discussion will indicate the level of questioning. Suggest ideas to improve the depth of questioning as you monitor. This activity can be used as a homework check or classwork assignment. The quickwrite can be read to see if the student addresses questions about the reading and the clarity of the ideas expressed.

Get Curious and Ask Questions

How can you improve your reading and thinking you ask? You can start by asking the big six on a regular basis:

- Who?
- What?
- Where?
- When?
- Why?
- How?

Notice that some of these questions don't always apply to a scientific subject or topic. In chemistry or physics, for example, you will rarely ask the question *Who*? In general, questions beginning with the words *How* and *Why* are more important. These questions force you to explore the material. You have to think about the ideas more deeply. Questions beginning with who, what, where, or when have more direct answers. Asking *why cancer occurs* is going to require more analysis than asking *When or Where* it was found in the body.

What makes a question worthwhile?

It would be impossible to list every question you can dream up; you are limited only by your imagination. Some questions are better than others are. How can you tell if a question is "good"? A good question tends to have more than one answer and has provocative implications.

Here are four powerful questions you can utilize to help improve your reading comprehension.

So what?	How is this significant? What does it tell us about other things? *(What does the fact that all life is made of cells tell us?)*
Says who?	Is this a fact or someone's opinion? How can this be verified? Does this depend on a particular point of view? *(How do we know that cells replicate their DNA?)*
What if…?	What would happen if...? What if I...? *(What would happen if CELLS stopped dividing?)*
What does this remind me of?	Where have I seen something like this before? What does that suggest? What do I know about this? *(What does the cell cycle remind me of?)*

Activity 3.4 (3 of 3) *Student Handout* (2 of 2)

Procedure

1. Skim the reading assignment. Use a pencil to write question marks where you feel you could ask a worthwhile question.
2. Divide your paper into four squares. Respond to the following four powerful questions.

So what?	**Says who?**
What if…?	**What does this remind me of?**

Having a Conversation With Yourself

Timeline

30–50 minutes depending upon reading selection

WIC-R Strategies

- Writing
- Inquiry
- Reading

Concept Statement

Good readers employ a variety of strategies to insure understanding and learning from reading material. The Student Handout provides a structure for organizing a series of questions that students should ask and answer when encountering difficult readings. Students need to apply these self-questioning strategies as they read. This strategy, in conjunction with vocabulary development, is a good way to facilitate the development of effective reading skills, especially for students who have a difficult time reading and understanding rigorous text.

Lesson Plan

1. Select a reading that will challenge students. You may want to provide a variety of readings so that students can select an appropriately difficult one. Difficulty is usually based on length of sentence, sentence construction and vocabulary levels.

2. Provide students time to read the article and to practice the questions on the Student Handout.

3. Have class generate a list of vocabulary that proved difficult and debrief the strategies that they used to determine the definitions. Have students provide examples of context cues and root word derivations to show other students how to apply these strategies.

4. Have students discuss (in small groups or as a class) why reviewing and skimming is an important step to reading. Solicit other strategies that students use to improve their reading comprehension.

5. Return to this skill often throughout the term. Each time provide a blank conversation handout for student notetaking.

6. Checking for completeness or collecting and grade are two options for this project. This activity is good for difficult reading assignments. Building discussion based on these ideas is critical to student's feeling that the work is worthwhile and helpful to their reading comprehension.

Having a Conversation With Yourself

Read the assigned material and use the provided questions to develop responses. This activity will lead you through some strategies to make you a more efficient reader. Think of this as having a conversation with yourself. With practice, you will make the "conversation" part of your normal routine.

1. ***What am I reading?***
2. ***Why am I reading this?***
3. ***Preview the chapter***
   a. How is it organized?
   b. What do I know about the topic already?
   c. What do I expect the chapter to state about the topic?
   d. Do I need to use some kind of graphic organizer like a mind map?
4. ***Read the selection carefully***
   a. Where does the information fit into my graphic organizer?
   b. Do I need to read more slowly or do I need to speed up?
   c. What main words do I not understand?
5. ***Vocabulary Issues: What words do I not understand? For each word I don't understand, choose a way to figure out the definition and do it. List the words and their definitions on a separate paper.***
   a. I can use context clues to figure out what words probably mean.
   b. I can look for familiar word parts if it doesn't slow me down too much
   c. I can look it up now if it seems to be important to understand the rest.
   d. I can ask someone what it means.
   e. I can write it down and look it up later.
6. ***Review and Skim***
   a. Does my graphic organizer make sense?
   b. Have I missed any important ideas or vocabulary?
   c. Can I paraphrase the main ideas from memory?
   d. Can I apply the information to a new situation?
7. ***Questions to ask myself when I don't understand what I've read***
   a. What are the unknown vocabulary words? Can I guess what they mean?
   b. Are there sentences that don't make any sense?
   c. Are there concepts that are unfamiliar?
   d. Is the writing hard to follow? Are the sentences too long, or do they jump around?
   e. Am I getting lost in details and missing the big picture?
   f. Am I confused because the parts don't seem related or connected?

Paraphrasing—How I Show What I Know

Timeline

20–30 minutes to draft (depending on reading size and level)

10–15 minutes to peer review

20 minutes to redraft (possibly homework)

WIC-R Strategies

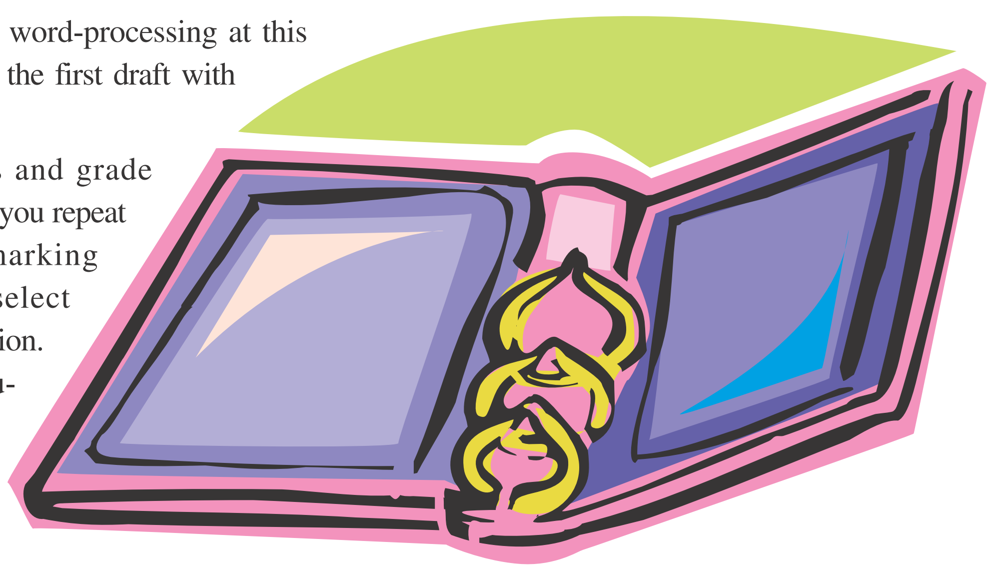
- Writing
- Collaboration
- Reading

Concept Statement

Reading is a skill that requires active engagement. If you can't explain to someone else what you have read, then you did not adequately understand the material. This activity focuses on helping students paraphrase what they have read, which enhances their reading comprehension as well as their writing skills.

Lesson Plan

1. Select and photocopy a reading selection. It is best to start with short (easier) readings and work up to longer ones. Keep the early ideas straightforward and clear.
2. Allow students to read at their own pace focusing on the main idea and the supporting details.
3. Distribute Student Handout "Paraphrasing—How I Show What I Know," and discuss. Also refer to overhead transparency.
4. Have students begin writing their paraphrase in class. Ideally, this entire process should be done in class several times. Give students 10–15 minutes to write their first drafts.
5. Allow students to review their work with a peer for 10 minutes.
6. Send the paraphrase home to be redrafted. Set the due date and the requirements for word-processing at this time. Decide if you want the first draft with the final copy.
7. Collect the final drafts and grade according to the rubric. If you repeat this several times a marking period, have students select their best two for evaluation. Later in the term, as students grow more adept at paraphrasing, first drafts will be gradable should you choose to do so.



Paraphrasing—How I Show What I Know

When you learn science, it is important to find the important ideas in the notes or text and to explain the ideas in your own words. Writing the ideas in your own words is called paraphrasing. Paraphrasing is really about thinking. You translate what the author has said into words and ideas that make sense to you. If you can paraphrase something you have read, then you really understand it.

Procedure

1. Find the main idea and supporting details in the paragraph and highlight them.
2. Rewrite the main idea sentence using your own words, adding important details. (This will form a summary statement.)
3. Reread your summary statement out loud. Do the sentences link up with one another in a way that makes sense? Is it clear to the reader what you are trying to say? Is it organized in a way that makes sense?
4. "Peer review" your draft with a partner. Make comments that help the writer to improve their writing. Note any ideas that are not expressed in the writer's own words.
5. Redraft your paraphrase summary. Clarify all parts that that not clear or does not make sense.
6. Turn in to your teacher as instructed.

Student Samples: Paraphrasing

Original text: The right hemisphere, it turns out, receives information only from the left side of the body, and the left hemisphere receives information only from the right side of the body. When you hold an object in your left hand, for example, only the right hemisphere of your brain detects the object. When you hold an object in our right hand, only the left hemisphere of the brain detects the object. Because you have a normal corpus callosum, both hemispheres receive this information." (From Santrock, John W. [1997] *Psychology.* Madison, WI: Brown & Benchmark.)

Student's Paraphrase: The right side of the brain gets information from the body's left side, and vice versa. The brain halves communicate through the corpus callosum, which is like a bridge.

Assessment of Sample: This sample clearly expressed the main idea of the reading, and goes on to give an analogy that cements that the student understands how the brain hemispheres work. This lacks details and examples that would be expected if the reading were longer. Writing is clear and logical. There are no mechanical errors.

Excerpt from original text: "Although Robert Koch was not the first to use experimental animals for the study of infectious disease, he was the first to use them in an integrated way with other methods." (From Brock, Thomas D. [1988]. *Robert Koch: A Life in Medicine and Bacteriology.* Madison, WI: Science Tech Publishers.)

Student's Entire Paraphrase: Robert Koch was the first scientist to combine the use of animals with other lab practices in studying infectious disease.

Assessment of Sample: This paraphrase discovers the main idea of the longer text segment but does not provide any details or examples about this concept. This paraphrase is more of a summary point that indicates a high-light not an idea in its entirety.

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"Today (AVID) is widely regarded as one of the most effective educational reforms ever created by a classroom teacher. The results have been extraordinary."

—Andrew Goldstein, *Time Magazine*

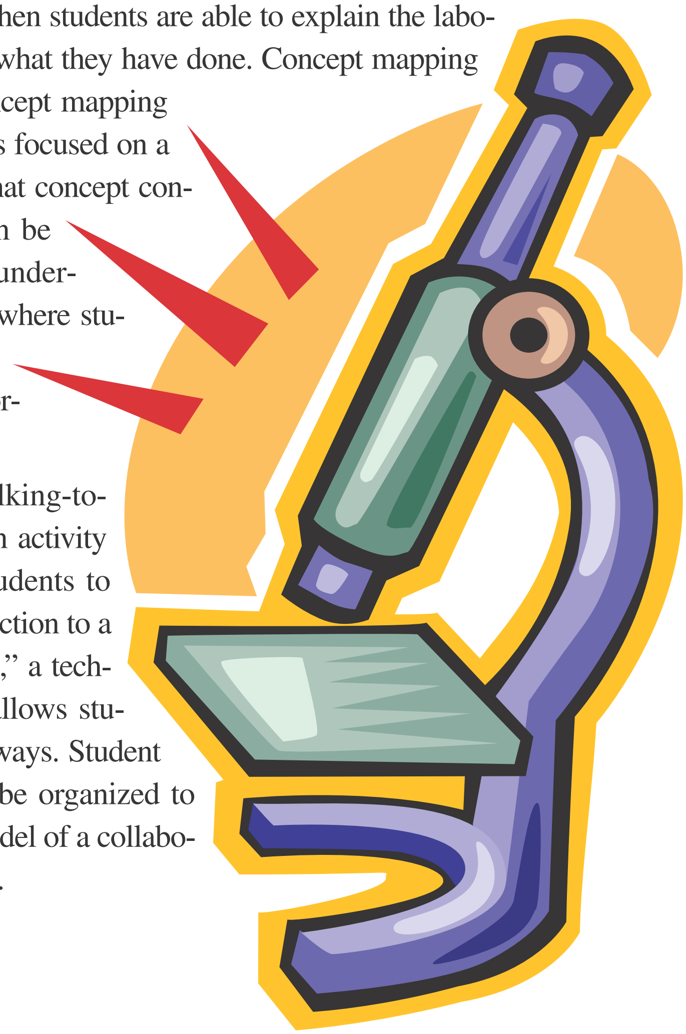
UNIT 4: TALKING TO LEARN IN SCIENCE

Overview

Goal: **To help students utilize a variety of classroom discussion and collaborative techniques to deepen their thinking and understanding of science content.**

A tool that science teachers often underutilize in science classes is using structured text-based conversations to enhance students' critical thinking skills. It is well worth while to delve into some of the benefits that students receive when they are allowed the freedom to speak about science issues that relate directly to science content.

Talking-to-learn strategies provide students the opportunity to dialogue with one another over content they are learning. For example, student learning is reinforced when students are able to explain the laboratory work to their peers and begin to make sense of what they have done. Concept mapping was introduced in Unit 1 and in this unit, a group concept mapping exercise is introduced producing a common map that is focused on a specific unit or topic. Students then dialogue about what concept connects to another and how these interconnections can be linked to other concepts, thereby articulating their understanding of concepts. Teachers benefit by finding out where students are confused (which is often not apparent until after a test) and to clarify these areas before a more formal assessment occurs.



The following unit highlights several distinct talking-to-learn activities. The unit begins with a text preparation activity called "Discussion Prep Log" This activity leads students to annotate text before discussion. Following is an introduction to a formal discussion technique called "Socratic Seminars," a technique that uses text and discussion procedures that allows students to explore topics in unrehearsed and interesting ways. Student "Lab Presentations" explore how student teams can be organized to present their findings to the class. Finally, we give a model of a collaborative team "Group Test" using the concept map format.

Discussion Preparation Log

Timeline

A reading is assigned as homework. (Note: Any assignment media that will result in discussion could be assigned, like a piece of music, a computer simulation, a scientific talk.) During the next class period, students will work in groups to debrief the reading. Class discussion will take approximately 20–40 minutes depending on the length of the article.

WIC-R Strategies

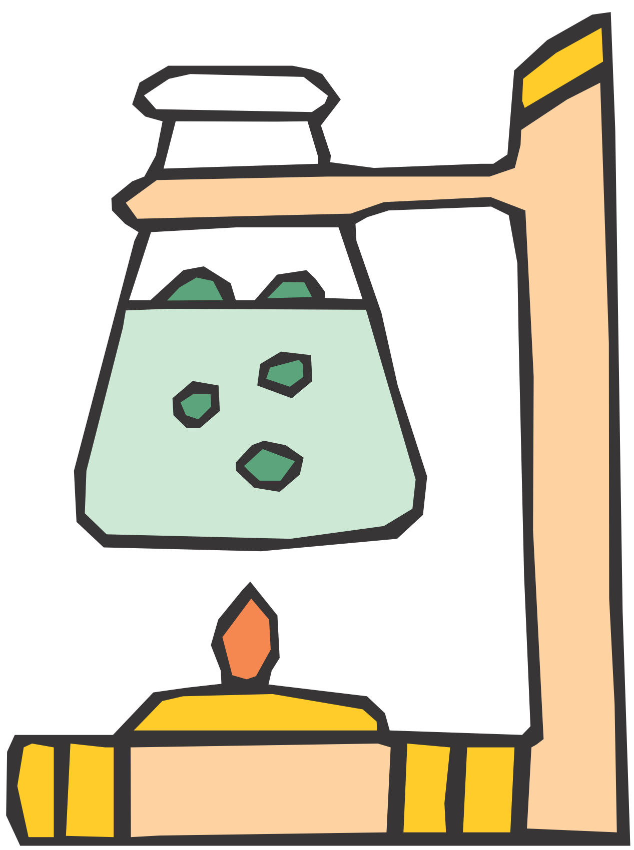
- Writing
- Inquiry
- Collaboration
- Reading

Concept Statement

The purpose of this activity is to structure student reading to better prepare them for a subsequent discussion. Students are asked to critically read content material, as well as record their personal reaction to the material. This dual reading and writing technique allows students to critically read, to think about the implications of the reading, and then verbally interact with their peers. These rich classroom discussions can provide fuel for further scientific exploration and the development of more critical thinking about how scientific knowledge impacts society at large.

Lesson Plan

This activity is best used once or twice a quarter to more deeply explore a current issue or 'hot topic' in the sciences. It is especially appropriate for examining the application of governmental or societal policy to areas of scientific interest. It is also useful to help students bridge what they are learning in science to what is happening in the larger world, a connection they often fail to make independently.



1. Select a reading article or passage that relates to the unit under study.
2. Instruct students to follow the first part of the Discussion Preparation Guide (see Student Handout).
3. The following day, have students do a Socratic Seminar on the topic. (See the guidelines for Socratic Seminars that follow).
4. Students should be evaluated in terms of preparation and completion of the Discussion Preparation Log. Students who do not prepare should not be allowed to participate in the discussion, but may listen, take notes, and submit their reflections at the end of the class discussion.

Discussion Preparation Log

Name ______________________________ Period__________ Due Date ____________________

Article Title: ____

Author(s): ____

While reading the article, highlight words or phrases that require definitions or clarifications.

Individual Assignment

- What are the AUTHOR'S **major** ideas, **concepts,** or **key points?**

  a. List these, point by point, and circle any you feel need discussion.

  b. Summarize the AUTHOR'S main point or idea in a few sentences.

  c. Write a reaction paragraph to the article stating your own thoughts on the topic, using specific citations from the article to support your views.

  d. Be ready to read and discuss your reaction paragraph in class on the due date.

Discussion Preparation Log

Name ____

Title of book section or article ______________________________

Part 1: **To be completed before discussion in class:**

Response Column

Record your questions, comments, and ideas for the "Text" entries. This is the intellectual history of your reading and will form the basis for our class discussion.

Text Column

As you read, record important points or quotes and page numbers. This gives you a summary of the material in the text.

Use this form or your InterActive Notebook

Response	Text

Activity 4.1 (4 of 4) *Student Handout* (3 of 3)

Response	Text

What is the author's argument in this passage?

Socratic Seminars

Timeline

Varies from approximately 30 minutes to 50 minutes. Allow 5–8 minutes for students to write a reflection/summary.

WIC-R Strategies

- Writing
- Inquiry
- Collaboration
- Reading

Concept Statement

In theory, learning occurs at deeper levels when students use critical thinking to resolve cognitive conflicts that arise when they are presented with alternative perspectives, ideas, or contradictions that students have previously learned or believed. The "Socratic Seminars" is a technique that allows students to critically read, to think about the implications of the reading, to verbally interact with their peers, and to logically record their thinking processes. These rich classroom discussions can provide fuel for further scientific exploration and the development of more critical thinking about how scientific knowledge impacts society at large.

Lesson Plan

This activity is best used once or twice a quarter to more deeply explore a current issue or 'hot topic' in the sciences. It is especially appropriate for examining the application of governmental or societal policy to areas of scientific interest. It is also useful to help students bridge what they are learning in science to what is happening in the larger world, a connection they often fail to make independently.

1. Review lesson materials before presenting information to students.

2. Find a relevant article from the newspaper, a journal, or a magazine that addresses a scientific issue (your text may have topic essays included which can also be used).

3. Assign students to read the article the day before the seminar and to take notes and create some questions.

4. Have students use "The Socratic Seminar Planning Form" to prepare for the "Socratic Seminar." (Other forms needed follow this page.)

5. On the Socratic Seminar day, randomly select 10–12 students to sit in the inner circle. Ask them to bring the text and their notes with them. Students outside the circle are assigned to 'watch' one person in the circle and to keep track of how often they speak and participate in the discussion. The two groups may switch places after about 15 minutes of discussion.

6. For your first Socratic Seminar, emphasize how the outer circle will be the observers—a very important role for scientists to learn. The data they collect will help to improve the process. Like any skill, this discussion technique takes practice, but is well worth the effort.

Socratic Seminar Procedure

1. "Inner-Outer Circle"

After reading the article, students split into an inner circle and an outer circle. The roles of each group are delineated below. Inner/Outer circle can be configured using various methods; but avoid more than 15 in the inner circle.

Roles of the Inner Circle

Students discuss what they have read. Members do not have to speak or respond, but are encouraged to participate when they can. It is okay to have periods of silence while people are thinking about what was said. No one in the outer circle may speak unless they are in the "Hot Seat."

Roles of the Outer Circle

- Students in the outer circle focus on one individual in the inner circle. The outer circle student observes this inner circle student and records data on the "Observation Form," like the number of statements, questions, summaries, times talking over another person, times not letting someone finish their thought, interruptions, invitations to speak, and other interesting behaviors.
- Provide students with a copy of the "Socratic Seminar Observation Form." Students write their names on the sheet and the name of the person they are observing.

Role of the Hot Seat

An empty chair in the inner circle. A member from the outer circle may take the "Hot Seat" one time to make a statement or comment, and then move back into the outer circle. No one may be allowed to wait behind the "Hot Seat" to speak.

2. Opening Questions for the Inner Circle

The key to a good question is that it opens up the floor to discussion about the article. It must invoke the higher-level thinking skills of Bloom's Taxonomy and the higher orders of questions suggested by Costa. Questions that force students to examine the themes of the piece or the implications of the piece are essential for successful seminars.

Possible opening questions for Inner Circle of Socratic Seminar.

- Where in the selection did you agree or disagree with the author's point of view?
- What could be another title for this selection?
- Is there any truth in this selection?
- What other evidence could you add to the author's?
- As a result of reading this selection, how has your opinion on the topic changed?

3. Outer Circle Final Statement

Go around the outer circle at the end of the seminar and give students the opportunity to make a statement or comment on...

- Their observations and thoughts about the themes that were brought out in the discussion.
- Any question they might have about the Socratic process.

  Note: A student may choose to pass on speaking.

Collect the observation forms from the outer circle.Consider having students from outer circle share their observations with the person they observed prior to turning in forms.

Elements of Socratic Seminars

Socrates believed that enabling his students to think for themselves was more important than filling their heads with "right" answers. In a Socratic Seminar, participants seek deeper understanding of complex ideas through rigorously thoughtful dialogue, rather than by memorizing bits of information or meeting arbitrary demands for coverage.

A Socratic Seminar fosters active learning as you explore and evaluate the ideas, issues, and values in a particular text. A good seminar consists of four independent elements: (1) the text being considered, (2) the questions raised, (3) the seminar leader, and (4) the participants. A closer look at each of these elements helps explain the unique character of a Socratic Seminar.

The Text

Socratic Seminar texts are chosen for their richness in ideas, issues, and values and their ability to stimulate extended, thoughtful dialogue. A seminar text can be drawn from readings in literature, history, science, math, health, and philosophy or from works of art or music. A good text raises important questions in the participants' minds, questions for which there are no right or wrong answers. At the end of a successful Socratic Seminar, participants often leave with more questions than they brought with them.

The Question

A Socratic Seminar opens with a question either posed by the leader or solicited from participants as they acquire more experience in seminars. An opening question has no right answer; instead it reflects a genuine curiosity on the part of the questioner. A good opening question leads participants back to the text as they speculate, evaluate, define, and clarify the issues involved. Responses to the opening question generate new questions from the leader and participants, leading to new responses. In this way, the line of inquiry in a Socratic Seminar evolves on the spot rather than being pre-determined by the leader.

The Leader

In a Socratic Seminar, the leader plays a dual role as leader and participant. The seminar leader consciously demonstrates habits of mind that lead to a thoughtful exploration of the ideas in the text by keeping the discussion focused on the text, asking follow-up questions, helping participants clarify their positions when arguments become confused, and involving reluctant participants while restraining their more vocal peers.

As a seminar participant, the leader actively engages in the group's exploration of the text. To do this effectively, the leader must know the text well enough to anticipate varied interpretations and recognize important possibilities in each. The leader must also be patient enough to allow participants' understandings to evolve and be willing to help participants explore non-traditional insights and unexpected interpretations.

Assuming this dual role of leader and participant is easier if the opening question is one that truly interests the leader as well at the participants.

The Participants

In a Socratic Seminar, participants share with the leader the responsibility for the quality of the seminar. Good seminars occur when participants study the text closely in advance, listen actively, share their ideas and questions in response to the ideas and questions of others, and search for evidence in the text to support their ideas.

Participants acquire good seminar behaviors through participating in seminars and reflecting on them afterward. After each seminar, the leader and participants discuss the experience and identify ways of improving the next seminar. Before each new seminar, the leader also offers coaching and practice in specific habits of mind that improve reading, thinking, and discussing. Eventually, when participants realize that the leader is not looking for right answers but is encouraging them to think out loud and to exchange ideas openly, they discover the excitement of exploring important issues through shared inquiry. This excitement creates willing participants, eager to examine ideas in a rigorous, thoughtful manner.

The major distinctions between dialogue (as used in Socratic Seminars) and debate.

Dialogue is collaborative: multiple sides work toward shared understanding.	Debate is oppositional: two opposing sides try to prove each other wrong.
In dialogue, one listens to understand, to make meaning, and to find common ground.	In debate, one listens to find flaws, to spot differences, and to counter arguments.
Dialogue enlarges and possibly changes a participant's point of view.	Debate affirms a participant's point of view.
Dialogue creates an open-minded attitude: openness to being wrong and an openness to change.	Debate defends assumptions as truth.
In dialogue, one submits one's best thinking, expecting that other peoples' reflections will help improve it rather than threaten it.	Debate creates a closed-minded attitude, a determination to be right.
Dialogue calls for temporarily suspending one's beliefs.	In debate, one submits one's best thinking and defends it against challenge to show that it is right.
In dialogue, one searches for strengths in all positions.	Debate calls for investing wholeheartedly in one's beliefs.
Dialogue respects all the other participants and seeks not to alienate or offend.	In debate one searches for weaknesses in the other position.
Dialogue assumes that many people have pieces of answers and that cooperation can lead to workable solutions.	Debate rebuts contrary positions and may belittle or deprecated other participants.
Dialogue remains open-ended.	Debate assumes a single right answer that someone already has.
Dialogue is ongoing.	Debate demands a conclusion.

Socratic Seminar Planning Form

Title of Seminar: ______________________________

Date:______________________ Class: ______________________

Article Title & Author: ______________________________

____

Main Concepts/ Issues	**Preliminary Activities**	**Seminar**	**Post-Activities**
Main ideas, vocabulary, coaching focus	Pre-writing activity, cooperative groups, background info.	*Opening question:* open-ended, raises issues, refers to text *Core question:* focuses on specific section in text for examination *Extending question:* expands/relates ideas generated during discussion	Debriefing and writing activities to further develop ideas from discussion

Reflections:

Observation Form: Inner-Outer Discussion Circle

Your Name ____________________ Partner ____________________

DIRECTIONS: Each time your partner does one of the following, put a check in the box.

SPEAKS IN THE DISCUSSION

LOOKS AT PERSON WHO IS SPEAKING

REFERS TO THE TEXT

ASKS A QUESTION

RESPONDS TO ANOTHER SPEAKER

INTERRUPTS ANOTHER SPEAKER

ENGAGES IN SIDE CONVERSATION

AFTER DISCUSSION: What is the most interesting point your inner circle partner made?

____

____

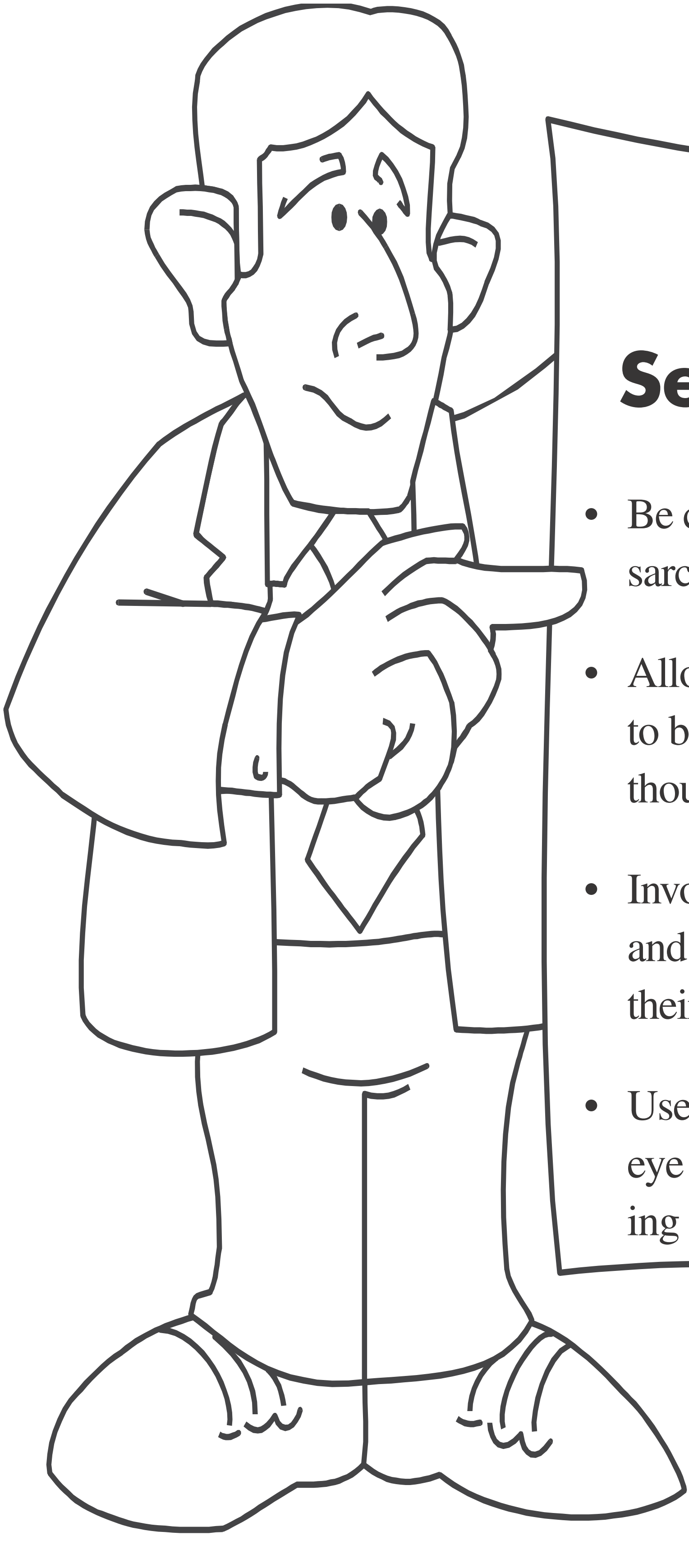
____

AFTER DISCUSSION: What would you like to have said in the discussion?

____

____

____



Socratic Seminar Rules

- Be courteous. No put-downs or sarcasm.
- Allow each speaker enough time to begin and finish his/her thoughts.
- Involve others in the discussion and ask others to elaborate on their responses.
- Use active listening skills through eye contact, nodding, and providing feedback.

Lab Presentations

Timeline

Varies; best if 5–7 minute time limit is set for presentation

WIC-R Strategies

- Writing
- Inquiry
- Collaboration
- Reading

Concept Statement

Not only do students need to communicate their ideas clearly in writing, but they also need a structured opportunity to verbally articulate the science concepts and procedures they are learning. Lab presentations are one vehicle for fostering scientific dialogue among students that also mirrors the real work of scientists. This activity is designed to allow students to steer the class conversations following a lab activity, rather than having the teacher provide the answers as students passively check their work. One student team presents their findings from the lab with a discussion of the tables and graphs from the experiment. They explain the meaning of the data generated as well as a description of how to complete the necessary calculations. Then this team summarizes the meaning of the lab information into the core concepts or 'big ideas.' Other teams then pose questions to the presenters for clarification or critique.

Through the preparation, each lab team must be able to discuss the organization of their prepared remarks as well as the content. Each team member must understand the lab and be prepared to discuss his or her findings as a participating team member. It is usually best if the team has a written guideline to follow that includes a rubric with the teachers' grading and performance expectations.

Lesson Plan

This activity is best used following labs, using set procedures in which the entire class completes the same investigation.

Requiring one lab presentation per team per quarter (one per week in the class) seems the best way to effectively implement this strategy. This schedule allows each team time to improve their performance over time and practice and their skills as well as allows students to see a variety of presentation styles. Teams are assigned or select their week or lab at the start of the quarter to allow students to plan their time wisely and know when they will be leading the lab discussion. It is important to post this information in the classroom for all to see. At the AP level, students learn quickly that it isn't always best to present the last week of the quarter, while Pre-AP students may need more direct instruction and modeling.

Requiring students to prepare notes for their first presentation and turn these in following the lab discussion increases their level of accountability and leads to more productive discussions following the presentations. One possible method for this is the "Discussion Preparation Log" format. Distribute Student Handout "Teem vs. Individual Responsibilities for Lab Work," and use direct instruction to prepare students for effective lab presentations. Have students critique a sample presentation to help them zone in on the most important lab information to present.

Team vs. Individual Responsibilities for Lab Work

Why have lab teams if I have to write it up myself?

You will often work as a team of three in the lab to collect data. This is to provide you support in the lab and foster the genuine exchange of scientific ideas. Each individual is expected to fully engage in the lab activity both physically and mentally. One of the complaints at the college level is a lack of lab skills of incoming students. The only way to develop these skills is through participation. A part of your lab grade is the satisfactory identification and use of lab equipment and chemicals. It is the responsibility of the team to complete the lab safely and accurately. Lab teams share credit on all shared work including but not limited to: accuracy of data collected, clean up points, safety rules adhered to and efficient usage of lab time.

What things can I do to be successful with labs?

Get to work immediately after the lab introduction. While waiting for reactions to occur or heating to occur, you should gather any required materials, clean glassware or discuss the lab (e.g., discuss the accuracy, organization and meaning of the results of your experiment) with your team. This does not mean less work, just more productive work. Use all the "spare" time for lab related work and talk.

How do I choose a good lab team?

A good lab partner is an invaluable tool in a science class. A good lab partner is responsible, hard working and dedicated. They are willing to participate in the physical completion of the lab and the mental analysis of the lab. A good lab partner completes his or her share of the work as agreed between team members. Another part of a good team is showing up when it counts. This means that they show up ready to go. The class cannot wait for unreliable teams on presentation days so team members who do not show up will have to present to the teacher at a time of his/her choosing and the other team members are still expected to present to the class.

Individual Responsibility

Each individual is expected to keep his or her own set of lab observations and data. Lab reports, calculations and quizzes are completed on an individual basis. The data collected in lab will be the same, but the presentation and interpretation of the data are unique to each science student. This means that the final decisions about how to organize data and results, how to interpret these results and how to apply these results to the laboratory work are yours and yours alone. This applies to all parts of lab reports. Identical parts, sections or entire lab reports are not considered for credit. *Academic dishonesty will not be tolerated.* This applies to plagiarism of a lab partner as well as other sources used for background information.

Lab Presentation

Each team is expected to present one lab per quarter. The presentation will take place on the class meeting immediately following the lab. The 4–6 minute presentation will include a discussion of the aggregate class data, an interpretation of the data, how the data compared to the expected outcomes (i.e., % error), sources of error in the lab, concerns about the reliability of the data and possible explanations of the data. Each individual team member is required to speak during this presentation to earn credit. A visual (chart, overhead, poster, etc.) is required. Evaluation of the presentation will include presentation skills and content. Review the rubric for the specific items that are being evaluated.

Lab Presentation Rubric

(50 points)

Lab Title: ________________________________ Lab Group: ____________________

PRESENTATION COMPONENTS	SCORE
Content *(30 points)* ☐ Data presented is relevant to problem stated ☐ Discusses expected results and collected results ☐ Discussion of anomalous data ☐ Discusses accuracy & precision of results ☐ Sources of error are specific ☐ Interpretation of data is clear and concise ☐ Can answer questions from class members	
Organization & Preparation *(5 points)* ☐ Team is prepared ☐ Presentation is coherent ☐ Logically organized ☐ Flows smoothly ☐ All team members participate in presentation	
Style *(5 points)* ☐ Opening is engaging ☐ Consistent eye contact with audience ☐ Appropriate voice volume ☐ Smooth transitions between speakers on team ☐ Gestures are appropriate	
Visual: Quality and Usage *(7 points)* ☐ Is useful to show data ☐ Is useful to show trends ☐ Table(s) &/or graph(s) are labeled ☐ Includes averages when appropriate ☐ Color is used appropriately ☐ Visual(s) are neat and legible ☐ Skillfully incorporated into discussion	
Time Speaking (3 points) 4–6 minutes = 3 points; over or under = 0 points	
Total Score:	

Concept Map Group Tests

Timeline

Minimum 45–90 minutes (It takes students 20 minutes to get a good directional flow going.)

WIC-R Strategies

- Writing
- Inquiry
- Collaboration

Concept Statement

Students need opportunities to process what they are learning. Students will, if given the opportunity, become intrigued with the task of connecting concepts. They can help each other negotiate difficult areas, review with each other and construct a product that elaborates their joint learning. It is amazing how hard students work on this. If the teacher reviews the same information before a test, he/she is in lecture mode and students are doing very little work. If students are doing their own structured review (and must produce a product), the teacher is freed up to check with groups and to monitor their understanding.

Lesson Plan

1. Instruct students that they will be given a group test—they will share a score on their jointly constructed concept map (see rubric in Unit 1). Have students bring their notes (InterActive Notebooks) and other pertinent papers (no texts can be used).

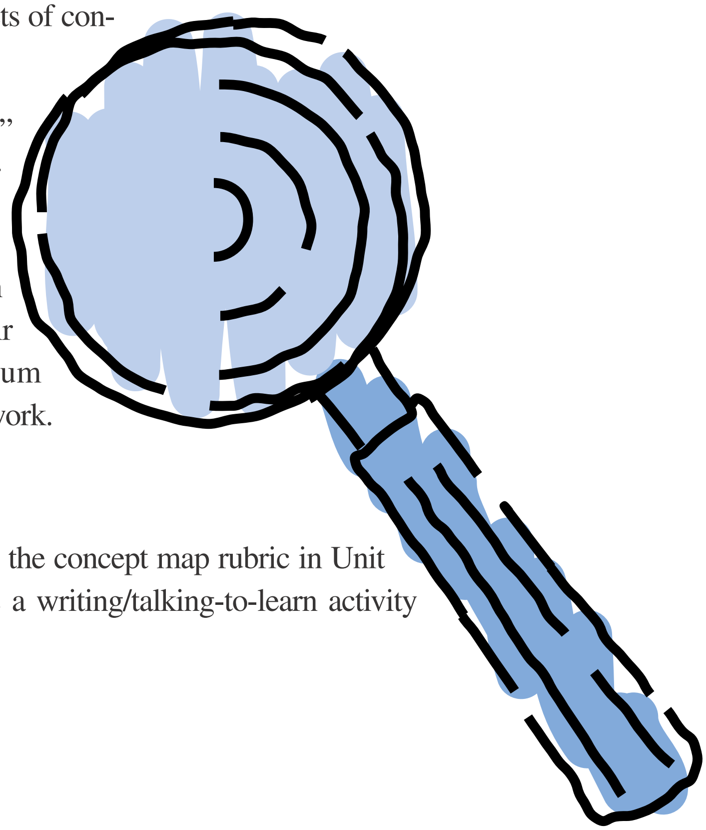
2. Provide students with butcher paper or large sheets of construction paper, felt tip pens, etc.

3. Hand out the "Sample Concept Map Group Test." Choose the appropriate sample activity for your class.

4. Allow students to work for about 45 minutes on constructing their maps. Have students post their maps and then allow students to do a 'museum walk' in their groups to look at their classmates' work.

5. Collect the maps for evaluation.

6. To assess, one option is to grade the maps, using the concept map rubric in Unit 1, and assign scores. Another is to consider this a writing/talking-to-learn activity and give credit for participation and completion.



Sample Concept Map Group Test - Biology

Names: ______________________ ______________________ ______________________

Organize the following key terms into a concept map. Don't forget to connect all terms, and include *linking phrases* between each connection. You must stay in your own group. You'll have 45 minutes to complete this. *Your grade will be based on depth of understanding of the concepts and clarity of your concept map.*

Key Terms

Natural selection	Founder effect	Hardy-Weinberg Law
Evolution	Mutations	Gene flow
Genetic drift	Adaptive radiation	Speciation
Bottleneck		

Hints for Mappers

1. Organize the terms into subgroups.
2. Find the term that includes all the others
3. Begin with the "larger term" and branch out.
4. Use connecting statements between concepts (terms) that explain the term. USE sub-branches to give SPECIFIC examples.
5. Use color and diagrams, too.

ROUGH DRAFT REQUIRED... ATTACH TO THIS PAGE!

Sample Concept Map Group Test - AP Chemistry

Electrons and Wave Theory

Use the following words to create a concept map about electrons. Show relationships with linking words. Quality of understanding as communicated by the map is the first priority.

- n, l, m_l, m_s
- orbital
- shape
- s, p, d, f
- charge
- Hund's Rule
- frequency
- Balmer series
- bright line spectra
- location
- quantum mechanics
- classical mechanics
- valence shell
- wavelength
- Pauli exclusion principle
- Heisenberg uncertainty principle
- waves
- standing wave
- particle
- lanthanide
- actinide
- transition metals
- Noble gases
- energy level
- electron configuration
- orbital diagram
- Aufbau

Use this table to organize the words that fall into an "easy" subtopic.

UNIT 5: THE NATURE OF SCIENCE: SETTING THE FOUNDATION FOR CRITICAL THINKING

Overview

Goal: **To give students a foundation for the underlying assumptions of all scientific work and to learn how critical thinking is an essential part of the scientific endeavor.**

The aim or goal of science is to understand and explain how the *natural* world works and how it got to be the way it is (NOT merely to collect "facts" about or descriptions of the natural world). It cannot answer questions of a moral, social or spiritual nature since these are outside of the area of legitimate scientific study. Science operates from certain premises or assumptions that are crucial to understanding the nature of scientific inquiry but which are seldom ever explicitly stated.

1. We humans can know and understand the world using our senses (and tools that extend our senses).
2. Natural events or phenomena have underlying causes, that is, we can explain the natural in terms of the natural.
3. The natural world is uniform, that is, natural processes are the same throughout the physical universe with respect to both space and time unless we have empirical evidence to the contrary (the principle of UNIFORMITY).
4. Scientific decisions on what ideas to accept frequently depend on argumentation using criteria other than certain truth. The decision as to when the criteria are sufficiently met by the evidence always depends on value choices.
5. Scientific decisions often reflect social and historical context, especially in language, metaphors and images, and problems emphasized. (e.g., the atom is like the solar system, the brain is like a computer).
6. As our understanding of these aspects of science has advanced and new evidence has accumulated, we have revised the models we use to describe science.

(*Adapted from* M. Nickles (1992), *Some Thoughts on the Nature of Science,* unpublished manuscript).

Scientific knowledge is *NOT CERTAIN* (that is, absolutely, eternally, and infallibly TRUE). Scientific knowledge is, however, CONTINGENT knowledge in terms of being based only on the available evidence and research, which is dependent on our senses and technology. Therefore, scientific knowledge is *SUBJECT TO MODIFICATION* in light of new research discoveries and/or analysis. In other words, *science deals with evidence, not proof.* This is an area that often confuses students. They will say, "I proved my hypothesis" when doing a simple confirmation experiment. This fundamental confusion, that science "proves" which implies "truth and certainty" must be addressed in all science classes.

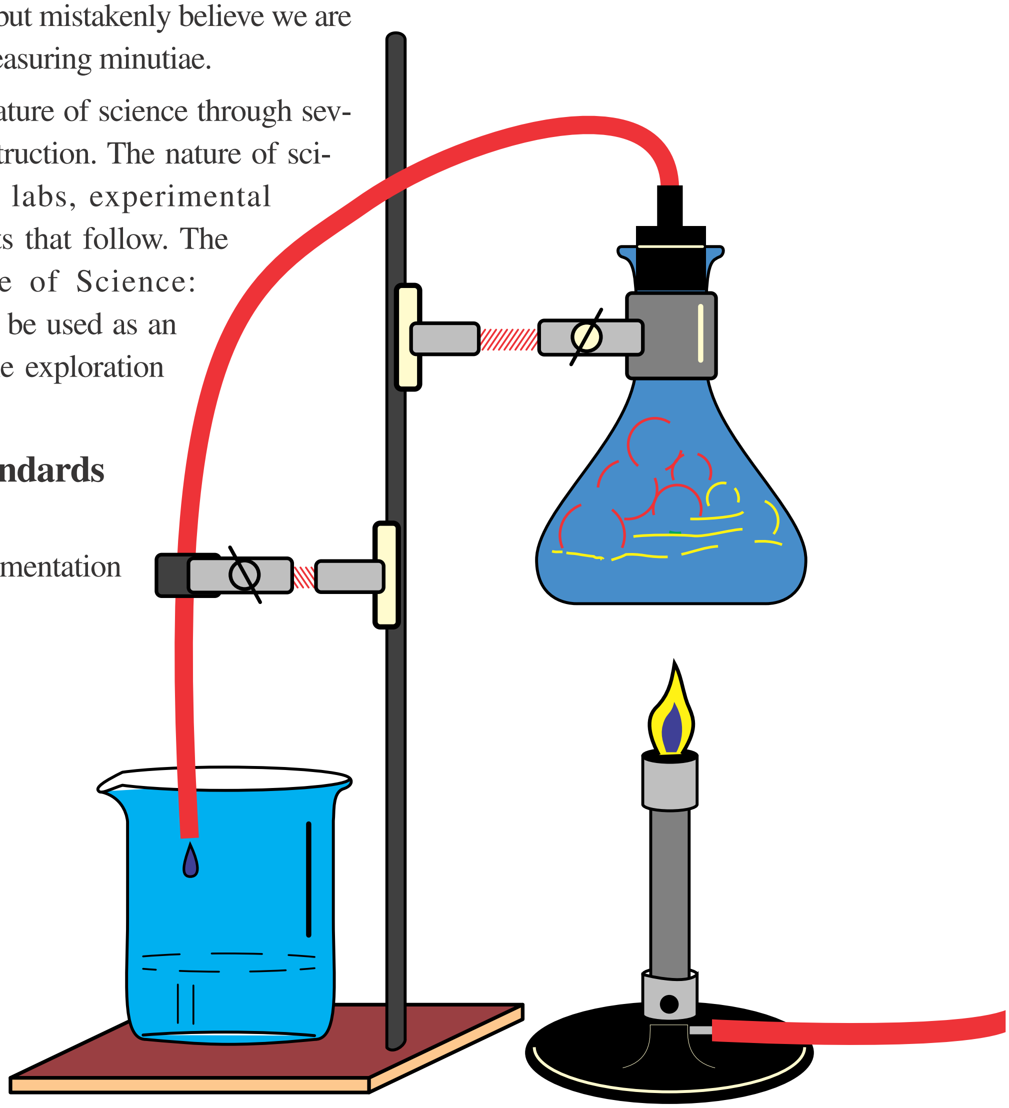
The more students understand that science is fundamentally uncertain and subject to immense change, the better able to understand that this very uncertainty is a strength not a weakness. Science students must understand what science can and can't do and which questions are genuine areas for scientific investigation and which belong in the realm of social and political action.

If students are to become critical thinkers in science, teachers must give them the required tools. Science is the discipline that has epitomized the critical thinking model through use of detailed scientific methods, experimental design criteria and reliance on evidence and data to draw inferences. Scientists exemplify critical thinking at its best and their stories can be used to both teach and inspire students. In science, both fundamental assumptions and current knowledge (even "facts") are subject to regular and rigorous re-assessment and inquiry. This is often not something students are aware of, hence the confusion over conflicting news stories. They must know that one scientist's conclusions and observations need to be duplicated by others to gain credibility. Our discipline's criteria for assessing the merits of different views tend to be explicit (i.e., empirical, verifiable, testable, and accurate). In the scientific community, varying degrees of uncertainty regarding the reliability of scientific knowledge at a given point in time is accepted as the normal state of affairs (or should be). In other words, science teachers may often encourage and promote skepticism. This will be news to many of our students who have not been introduced into the scientific community of learners, but mistakenly believe we are about collecting facts and measuring minutiae.

This unit explores the nature of science through several activities and direct instruction. The nature of science underlies all of the labs, experimental activities, and research units that follow. The following page, "Nature of Science: Concepts for Students," can be used as an overhead to use to begin the exploration about the nature of science.

California Content Standards Addressed

Investigation and Experimentation 1. d, f, k and n.



Nature of Science: Key CONCEPTS for Students

1. Science is limited to natural explanations of the universe using our senses.
2. Science is a process of problem solving.
3. Scientific knowledge is contingent upon previous knowledge and subject to modification.
4. Scientists have biases that influence their work. Human values deeply influence the questions scientists ask.
5. Science is collaborative—no scientist works alone.
6. Science involves choices between alternative theories based on evidence.
7. Science is usually fundamentally uncertain.
8. Science is a human invention.

Characteristics of Critical Thinkers

Timeline

Varies from 20–25 minutes

WIC-R Strategies

- Writing
- Inquiry
- Collaboration

Concept Statement

Critical thinking describes the cognitive process of reflecting on, and assessing, the assumptions/premises and the underlying alternative viewpoints available. It also requires the ability to thoughtfully critique those viewpoints. Regularly remind students how to develop their inquiry skills:

A. Do **not** take things for granted (e.g., examine the assumptions and premises of a given intellectual position—even one's own as the teacher).

B. Do not rely upon nor acquiesce to *authority.*

C. Encourage *individual* consideration of diverse perspectives and alternative interpretations.

D. Presuppose that EVIDENCE is possible, but TRUTH is neither self-evident nor even attainable for scientists.

E. *Uncertainty* with respect to equally valid and meritorious interpretation is closer to reality than one 'right' explanation.

F. Require *individual* decision-making (in the face of uncertainty) through the process of making as explicit and conspicuous as possible the assumptions and reasons one uses when preferring one viewpoint over another.

Lesson Plan

The overhead/student chart, "Characteristics of Critical Thinker," is best used at the start of the year to introduce students to the critical thinking habits of mind necessary for scientific inquiry. It is recommended that you post it in classroom and refer to it often.

1. Ask students to open their InterActive Notebooks (left side) or use a piece of paper and get ready to write.
2. Have students write for 2–3 minutes on their definition of critical thinking. Ask them to list the characteristics of a critical thinkers, and jot down when they themselves have used critical thinking (be specific).
3. Have students pair-share their writing for 3–5 minutes.
4. Call for volunteers to read their definitions, lists, or situations for another 5 minutes.
5. Review the overhead "Characteristics of Critical Thinkers," and have students add to their lists. Invite commentary on how to use critical thinking in science.
6. Alternatively, have students continue to add to their list of times they have used critical thinking in your class as a refresher opening or closing classroom activity throughout the year.

Characteristics of Critical Thinkers

1. Critical thinkers are flexible—they can tolerate ambiguity and uncertainty.
2. Critical thinkers identify inherent biases and assumptions.
3. Critical thinkers maintain an air of skepticism.
4. Critical thinkers separate facts from opinions.
5. Critical thinkers don't oversimplify.
6. Critical thinkers use logical inference processes to examine interpretations.
7. Critical thinkers examine available evidence before drawing conclusions.

Human Soul Weighs 1/3,000th of an Ounce

Timeline

10–20 minutes, time varies depending on assigned writing.

WIC-R Strategies

- Writing
- Inquiry
- Collaboration
- Reading

Concept Statement

Students are bombarded daily with vast amounts of non-science or pseudoscience from a variety of sources. Students rarely have a chance to critically examine the claims made in these publications, but taken as "common knowledge" by many of their peers. This activity takes an actual headline and asks students to evaluate it from a scientific perspective. By modeling how to go about questioning the onslaught of pseudoscientific information, students can begin to apply these skills both inside and outside the classroom.

Lesson Plan

It's recommend that this be used early in the first semester to introduce critical thinking.

1. Make an overhead copy of the following fictional cover page, "Human Soul Weighs 1/3,000th of an Ounce."
2. Instruct students to get out their InterActive Notebooks and get ready to write.
3. Put the overhead up and ask students to write for 5–7 minutes about (a) what kind of experiment do they think was done, (b) what alternative hypotheses might account for the results, (c) if there is anything 'non-scientific' about the information given. *Look for student responses that include the following:*
   - Ounces are not a scientific measurement; metrics are.
   - Science can't study the supernatural, only the natural world, so this isn't an appropriate question. Science doesn't 'prove.'
   - Soul is said to be 'non material,' therefore would not have any mass.
   - When humans die, they release sphincter muscles controlling bladder and rectum, losing mass in body wastes. Exhaling breath could also have mass.
   - Who are the "top scientists?"
   - What type of equipment would be needed to conduct this experiment?
   - How much is 1/3,000th of an ounce? Do we have scales to measure this?
4. Have students share their written responses. Post their findings on the board.
5. Lead students in a discussion: "What are the limits of science?"

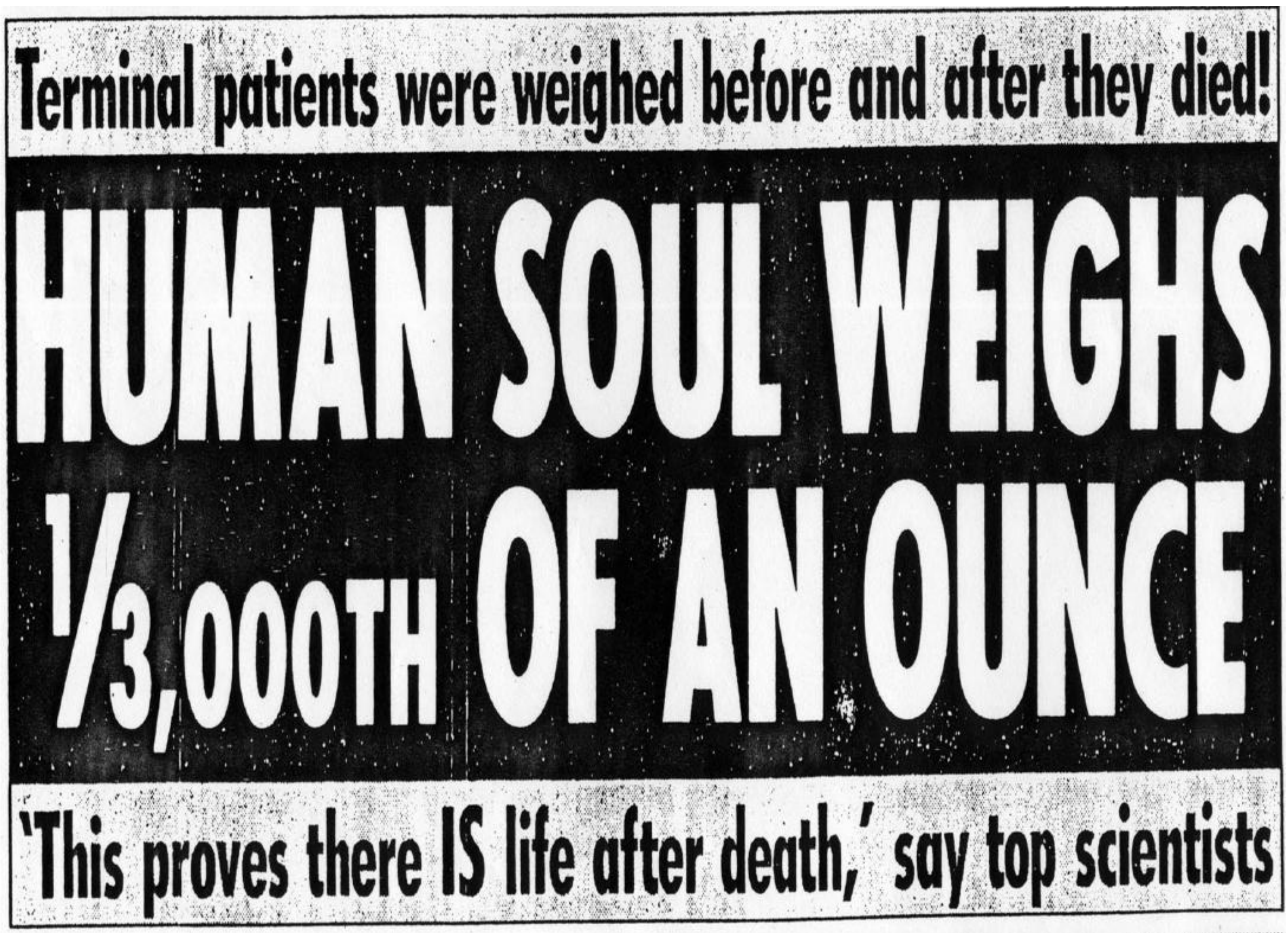
Instructions

In your InterActive Notebook, respond to the following questions.

a. What kind of experiment do they think was done?

b. What alternative hypotheses might account for the results?

c. Is there anything 'non-scientific' about the information given?


Terminal patients were weighed before and after they died!

HUMAN SOUL WEIGHS 1/3,000TH OF AN OUNCE

'This proves there IS life after death,' say top scientists

Limits of Science

Timeline

20–50 minutes depending on if assigned as homework.

WIC-R Strategies

- Writing
- Inquiry
- Collaboration
- Reading

Concept Statement

Students work through information about the specific criteria for the rules of science and how to distinguish good from poor science. The problems of pseudoscience, which claims to be scientific or confirmed by science, are also explored. Ignorance about the rules of science has led to much confusion about the nature of science and what science can and can't do. This, in turn, has led to the misuse of science in advertising, religion, and politics. This activity will further cement the concepts of how science is done and how to identify the flaws in poorly done science or pseudoscience.

Lesson Plan

This activity can be done the first week of school since it requires no prior knowledge and can generate classroom discussion about the nature of science.

1. Duplicate and distribute student handout packet, "The Limits of Science" and "Limits of Science: Activity & Inquiry for Inquisitive Science Students." Assign reading and activity as homework, possibly over a weekend.
2. When the assignment is due, check for individual completion and then have students get in lab teams and review the information with each other.
3. Ask students about how they responded to the information and if any of them have had experience with the 'pseudosciences.'
4. Spend some class time reviewing the rules of science. Consider giving a quiz on the information from the "Limits of Science."

The Limits of Science

Introduction

Science is a powerful tool. It provides a structure for looking at nature using our senses to explain our observations. But science also has its limits.

Limitations of Science

- Science must follow distinct rules.
- Science can only solve specific types of problems.
- Science can only use certain types of explanations.
- Scientific solutions are only attempts to explain nature. They are not facts.
- Science can be misused.
- Science can be done poorly.

The Rules of Science

Science must follow certain rules. All people involved in scientific exploration and discovery adhere to these rules. Ignorance about these 'Rules of Science' has led to much confusion about the nature of science and what science can and can't do. This in turn has led to the misuse of science in advertising, religion, and politics.

Four Important Rules of Science

1. Science cannot answer questions that require opinion, beliefs, or judgment as part of the answer.
2. Supernatural forces cannot be used as part of a scientific explanation.
3. Scientific explanations must be based on careful observations and the testing of hypotheses through experimentation.
4. It must be possible to *disprove* a hypothesis.

Questions Science Cannot Answer

Science cannot solve all problems. A basic assumption of science is that the laws of nature are the same everywhere. Those physical laws do not depend on opinion. People, however, have different customs, beliefs, and life styles. Many human questions require the use of opinion. For example:

- *"What is right?"*
- *"Who was the best president?"*
- *"Which religion is best?"*
- *"What is the purpose of human existence?"*

All of these questions require judgment or opinion to answer. Since the answers will be based on opinion, science cannot provide answers to such questions. Other areas of human thought, such as philosophy and religion, do deal with these questions.

Science was never meant to answer questions about matters of judgment, opinion, or belief. This is a key rule of scientific study. Science was developed to answer questions only about how nature works, based on physical observations (data).

Explanations Science Cannot Use

A hypothesis is a possible explanation to a question about nature. It must always be possible to *disprove* a hypothesis. This is also a critical rule of scientific inquiry. *Explanations which are impossible to disprove cannot be used in science.*

Some Explanations Impossible to Disprove

- Some of our behavior is caused by mysterious forces from the planets or stars.
- The origin of all of life forms was through God's creation.
- Some people can predict the future because they have a special ability.

A common feature of these explanations is that they require mysterious or **SUPERNATURAL FORCES.** A **supernatural force is a power which can do anything; the laws of the universe do not apply.** Such forces are not limited by the laws of nature, therefore, their actions cannot be predicted, or experimented on. To be able to disprove an explanation, we must be able to test it. This means, in science, we must be able to do an experiment.

Experiments to test a hypothesis must be carefully designed. The test must give a predictable result if the hypothesis is correct. If the hypothesis is incorrect, the results must be clearly different from the predicted result.

Supernatural forces may very well exist. Many people believe they do. But supernatural explanations do not give us predictable actions. Therefore, they cannot be used in any scientific way. **Scientific explanations can never include supernatural or mysterious forces to explain phenomena.**

Scientific Solutions Are Not Facts

The main goal of science is to understand nature by developing predictive theories, not to collect or produce facts. The scientific method is a very successful process for uncovering cause and effect problems. It has given us a reliable, workable picture of the real world. As a result, many people assume that a **SCIENTIFIC EXPLANATION** is a fact. This isn't so. An explanation is formed through observation and interpretation by rational thought (deductive and inductive reasoning.)

Facts are observations about nature generally accepted as true. They serve as evidence for or against theories. Although facts sometimes turn out to be wrong, such as: the sun circled the earth and species never change, we're usually pretty confident about whether something is a fact. For example, it's a fact that life has changed over time; that species once living are now extinct and that new species have taken their places.

Scientific theories are not facts. They are sets of statements, often called postulates, that explain facts and predict new facts. Newton's gravitational theory is a good example of a scientific theory. All good scientific theories have these characteristics:

- Theories have to be **economical,** they must explain much in few words.
- Theories must be **general,** a theory that requires a different postulate for every fact is useless. On the other hand,
- every theory is **limited** in scope; no scientific theory explains every imaginable fact.

- Theories must be **falsifiable;** we must be able to imagine some condition that, if true, would prove the theory wrong.

Good theories make specific predictions about what will and what will not happen in certain conditions. A theory that makes wrong predictions is false. A *prediction*, in science, means logical deduction, not wildly forecasting the future.

Scientific Explanations

Hypothesis: a possible explanation to a question about nature, based on observation.

Theory: a set of statements that explain and predict facts. They are economical, general, limited, falsifiable and predictive.

A "theory" as the word is used in common everyday English means just a possible idea. This is not how the word theory is used in science. **Scientists consider a theory to be very solid, and strongly supported by research and evidence over time.** For example, Einstein's Theory of Relativity has been upheld by research data over a period of 70 years and Darwin's Theory of Evolution by Natural Selection has been supported by a wide variety of research for over 140 years.

Observations and Facts in Science

Observations and facts involve what our physical senses tell us about the world. More than one possible explanation can be derived from the same observation, depending on the experience, knowledge and bias of the observer.

The Difference Between Observation & Fact

Observation: any information received directly by seeing, hearing, smelling tasting or touching (or through technological tools that extend our 5 senses).

Fact: an observation that appears the same to all careful observers, and therefore assumed to actually exist in nature.

Scientific explanations are attempts to describe how nature works, not to discover "the truth." Scientific explanations may be considered as likely to highly probable. But, s*cientific explanations are never a certainty.* There is always a chance that what was believed to be accurate could be disproved with additional evidence, observation and experimentation. Hypotheses and scientific theories are therefore clearly not facts. They are merely our efforts to understand the workings of nature based on facts.

The Misuse of Science: Pseudoscience

Some groups of people falsely claim that science has proven their beliefs to be "true." Any belief system that misuses science or claims to utilize scientific methodology to verify itself is called pseudoscience. Believers of a pseudoscience may attempt to do scientific studies to support their beliefs. They may also refer to other studies that only seem to support their belief system, and reject evidence that doesn't bolster their belief system.

Comparison of Pseudoscience and Science

Pseudoscience	*Science*
• Ignores certain rules of science.	• Follows the rules of scientific inquiry.
• Tries to prove own explanations.	• Tries to disprove own explanations.
• Includes supernatural forces in interpretations.	• No supernatural forces used in interpretations.
• Ignores or discounts contradictory research.	• Includes all related research, even if it does not support their interpretations.

When a pseudoscience is examined closely, certain rules of science are always missing. For example, supporters of a pseudoscience usually seek to prove their point of view, and do not undertake serious efforts to disprove it.

Proponents of pseudoscience also often use supernatural or mysterious forces as explanations of phenomenon. In addition, a belief in those forces is assumed as a required part of the explanation. These are clearly not acceptable procedures for scientific inquiry. Nevertheless, such groups usually keep claiming that their beliefs have been "proven" scientifically.

Examples of Pseudosciences

- ESP (Extra Sensory Perception)
- Astrology
- Biorhythms
- Hauntings/Ghosts
- Scientific Creationism
- UFO Studies
- Numerology
- Crystal Healing
- Tarot Cards

Pseudoscientific topics have often been studied carelessly. Poor scientific techniques were used or scientific rules were ignored. **The claims of pseudoscientific adherents have never been supported by the results of controlled scientific studies.**

Good Science vs. Poor Science

Some science is not reliable because it's poorly done. As you know, not everyone does a job well. The music played by some musicians sounds off-key. Some mechanics can't always repair a car properly. Some secretaries write letters with misspelled words. Likewise, some scientists may do poor research.

Sometimes, scientists may not be careful. Errors might be made in measurement or interpretation. Or, the experimental design may neglect to control important variables. These factors might be the real cause for the experimental results, and not be discovered.

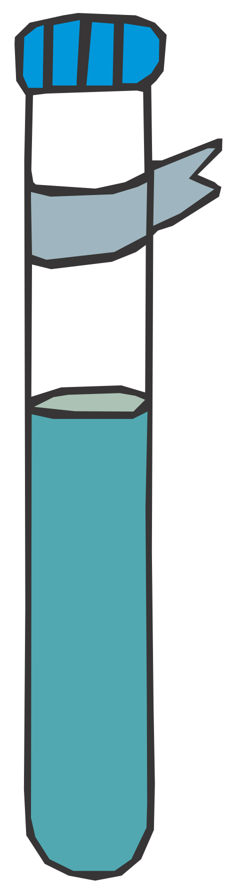
Scientists also have bias, as do all humans. They may be prejudiced toward a hypothesis and ignore bits of data which indicate an alternative interpretation. Properly designed experiments control researcher bias by using large test groups, controls, double-blind experiments and placebos.

Guidelines For Good Science... The Rules of Inquiry

1. **Controlled:** Only one variable at a time is tested experimentally.
2. **Repeatable:** Different scientists should be able to repeat the procedures, and get the same results.
3. **Cause-Effect:** Does "X" cause "Y" to happen? If so, a change in one must result in a matching change in the other. A large test group is used.
4. **Species-Specific:** Experiments with one type of plant or animal may not give the same results with other types (i.e., rats & humans).
5. **References:** All earlier studies of the problem should be considered and related to the present study.
6. **Published:** Research should be printed in reputable journals where they can be studied and repeated by other scientists. References to unpublished studies should be questioned.

Testing a hypothesis many times, in a myriad ways, by numerous scientists is one of the strengths of science. Errors made by one scientist would very likely be found and corrected by the other scientists. This system works well to make scientific conclusions more reliable. However, these conclusions are always subject to change based on new information and research. Scientific conclusions are not static, but are constantly under revision.

If a scientist makes many mistakes, his or her reputation will suffer. Other scientists may be suspicious of all studies published by these careless scientists. They may double check the studies, publicly criticize the work, or ignore it completely. Some science is not reliable because it is done in a shoddy or even dishonest manner. Working scientists may be in competition with each other for limited financial support from governmental grants and by private industry. Often scientists feel the need to produce "results" so that their funding will continue. For example, the National Geographic sponsors hominid fossil hunting trips to Africa. If the paleontologist come back empty-handed after a 6-month season, they are less likely to be funded again.



At times, the results of poor science will fit what someone else wants to see. This might be a politician or businessman who may not understand science. The experimental results may be used in misleading advertising, or to produce new laws. Due to these problems, many people have come to distrust science. This distrust stems from lack of understanding about the nature and goals of scientific research. Remember, science cannot solve all human problems, nor can "breakthroughs" be made on demand.

Note that both science and non-science produce practical applications. Since this is a science class, we will be concentrating on the study of "scientific inquiry," i.e., good experimental design, research techniques and analysis based on evidence.

Name ______________________________ Period __________ Due Date ____________

Limits of Science: Activity & Inquiry for Inquisitive Science Students

1. **Read** the research sample below, and each of the 5 features listed below it.
2. If you think a feature is an example of "good" science, write **GOOD** next to that number. **For each** "GOOD" science example indicate which guideline of "good science" was followed, from the reading "Guidelines for Good Science… The Rules of Inquiry."
3. If you think it is a feature of "poor" science, write **POOR** next to that number. **For each** "POOR" science example, indicate which guideline of "good science" was not followed.

Sweet Research Sample

A number of years ago, an artificial sweetener called "cyclamate" was legally banned. As a result of certain research results, no more cyclamate could be sold in the United States. Listed on the chart are some of the features. Using the information from the 'Limits of Science' reading, answer questions 1–12 using articulate and complete sentences.

Research Feature	Good/Poor?	Guideline for Good Science
1. Mixtures of cyclamate and saccharin (another artificial sweetener) were fed to 240 rats during their lifetimes. Tumors were found in 7 of 20 males and 1 of 30 females. It was concluded that cyclamate was responsible for the tumors.		
2. Different amounts of the mixtures were used, but only the rats receiving the highest dosage level developed tumors. The amount was equivalent to a person drinking 350 bottles of diet drink per day.		
3. According to some unpublished results of another study, chick embryos developed abnormally when given cyclamates.		
4. None of the several published studies on the effects of cyclamates on mammals have shown any abnormal embryo development.		
5. From the above observations, the FDA scientists concluded that cyclamates could be harmful to humans.		

Using the information from the "Limits of Science," answer the following questions, using articulate and complete sentences.

1. Of the six limitations of science, which do you think is most often ignored? Explain why. Use examples from your own reading and experience.

2. Why can't supernatural forces be used in a scientific explanation?

3. What does science assume about the laws of nature?

4. What kinds of questions can NOT be answered by science? Write two such questions of your own.

5. What must always be possible to do to a hypothesis? State a scientific hypothesis of your own.

6. What is the main goal of science? Does this differ from your previous understanding? How?

7. What are the key attributes of a scientific theory? How does "fact" differ from observation?

8. What do all types of pseudoscience have in common? Why are people so attracted to pseudoscience? Do you have a personal pseudoscientific favorite, why?

9. What three scientific "rules" are usually ignored by pseudoscience?

   a.

   b.

   c.

10. Why are scientific theories so reliable and predictive?

11. What are some characteristics of poorly done science?

12. Funding for many scientific studies here in the United States is provided by private companies (e.g., drug companies developing a new product), or by intense competition through the government in the form of grants. Does this method of financing science make an impact on the way the researches perform their experiments? Explain.

Activity 5.4 (9 of 10)*Answer Key: Limits of Science Activity* (1 of 2)

Research Feature	Good/Poor?	Guideline for Good Science
1. Mixtures of cyclamate and saccharin (another artificial sweetener) were fed to 240 rats during their lifetimes. Tumors were found in 7 of 20 males and 1 of 30 females. It was concluded that cyclamate was responsible for the tumors.	**Poor**	**3, 1**
2. Different amounts of the mixtures were used, but only the rats receiving the highest dosage level developed tumors. The amount was equivalent to a person drinking 350 bottles of diet drink per day.	**Good** (some may make a case for **Poor** however)	**1, 3, 4**
3. According to some unpublished results of another study, chick embryos developed abnormally when given cyclamates.	**Poor**	**4, 6**
4. None of the several published studies on the effects of cyclamates on mammals have shown any abnormal embryo development.	**Good**	**2, 4, 5, 6**
5. From the above observations, the FDA scientists concluded that cyclamates could be harmful to humans.	**Poor**	**1, 3, 4, 5, 6**

***** STUDENT ANSWERS WILL VARY SOMEWHAT**

Using the information from the 'Limits of Science,' answer the following questions using articulate and complete sentences.

1. Of the six limitations of science, which do you think is most often ignored? Explain why. Use examples from your own reading and experience.

   Varies by student.

2. Why can't supernatural forces be used in a scientific explanation?

   Science doesn't study the supernatural.

3. What does science assume about the laws of nature?

   They are uniform and constant everywhere.

4. What kinds of questions can NOT be answered by science?

   Those dealing with supernatural, politics, morals, etc.

   Write two such questions of your own.

   Varies by student.

5. What must always be possible to do to a hypothesis?

   Conduct an experiment to test it.

   State a scientific hypothesis of your own.

   Varies by student.

Activity 5.4 (10 of 10)*Answer Key: Limits of Science Activity* (2 of 2)

6. What is the main goal of science?

   To explore and understand nature.

   Does this differ from your previous understanding? How?

   Varies.

7. What are the key attributes of a scientific theory?

   A set of statements that explain facts and predict new facts.. They are economical, general, limited, falsifiable and predictive.

   How does "fact" differ from observation?

   A fact is an observation that is has been verified by many careful observers.

8. What do all types of pseudoscience have in common?

   Misuses science or claims to use scientific methodology to verify it's claims.

   Why are people so attracted to pseudoscience? Do you have a personal pseudoscientific favorite, why?

   Answers will vary.

9. What three scientific "rules" are usually ignored by pseudoscience?

   a. Ignores rules of science.

   b. Tries to prove own explanations.

   c. Includes supernatural forces and discounts research that doesn't support their views.

10. Why are scientific theories so reliable and predictive?

    Varies by students. Should include many years of testing, supported by lots of evidence.

11. What are some characteristics of poorly done science?

    Lack of careful adherence to the rules of science. Errors in measurement, experimental design, or lack of control groups. These scientist may be biased toward a hypothesis and ignore some results.

12. Funding for many scientific studies here in the United States is provided by private companies (e.g., drug companies developing a new product), or by intense competition through the government in the form of grants. Does this method of financing science make an impact on the way the researches perform their experiments? Explain.

    Varies by student—requires application and synthesis of ideas.

Types of Scientific Investigations

Timeline

20–50 minutes, depending on if reading is first assigned as homework.

WIC-R Strategies

- Writing
- Inquiry
- Collaboration
- Reading

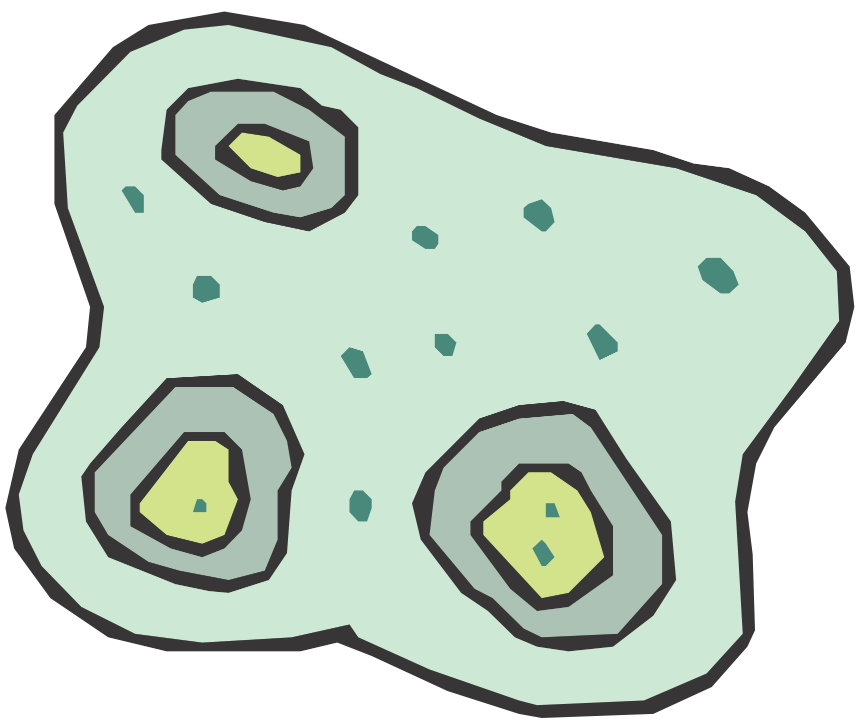
Concept Statement

Students will be introduced to the three main types of scientific investigations. These central types will be used in their textbooks to present the work done by other scientists, but students often don't know there are multiple legitimate ways to investigate a scientific question. The question asked frequently determines the methodology. The goal with this activity is to help students recognize the various types of research they will be asked to read about and perform themselves. As students begin to design and execute their own experiments in Unit 6, this information will be foundational for them.

Lesson Plan

This activity can be done early in the semester as students are learning about experimental design, but ***after*** *they have learned how to concept map.*

1. Duplicate student handout "Types of Scientific Investigations" and have students read it in class or for homework.
2. Have available chart paper, marker pens, and other concept map making materials.
3. Put students in collaborative groups and have them construct a concept map on the three types of research with specific examples and connecting phrases.
4. Have students present their group maps to another group. Using the concept map rubric from Unit 1, grade the maps or have students peer grade another group's map.
5. If computers are available, have students use *Inspirations* software to construct their maps.



Types of Scientific Investigations

Science is an exercise in creative problem solving. Scientists have to figure out how to make observations that will illuminate the puzzles they want to solve. When scientists or science students conduct research, two of the most pressing questions to answer are:

1. What kind of measure(s) am I going to use to collect data?
2. What research strategy will I use to carry out my study?

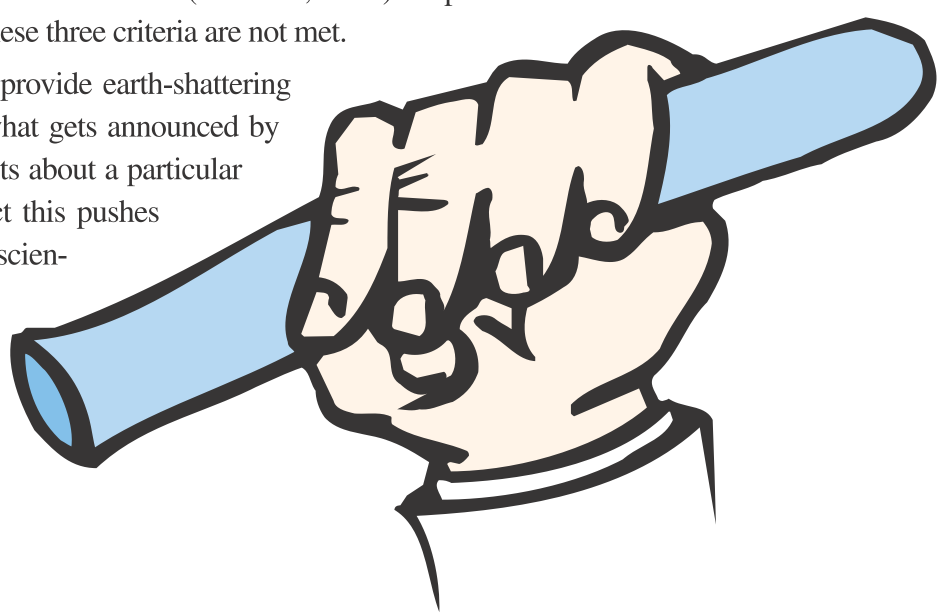
Different questions call for different strategies of research (Weiten, 1995). We can do research anywhere from the laboratory, to the ocean floor or from space. We can study both the living and non-living. Experimental research is a well-defined process for determining cause-and-effect relationships and is useful for most types of scientific investigations. However, some areas worth studying can't be experimentally tested, especially in cases where it may be unethical or impossible. For examples, we cannot experimentally test extinct species, nor can we intentionally harm our test subjects. Often research incorporates interviews, surveys, standardized tests, or case studies. Three of the most common research techniques are experimental, descriptive, and correlational.

1. Experimental Research: Cause-and Effect-Relationships

Experimental research allows us to determine and measure the cause-and-effect relationship between events. The experimenter actively changes an event *(the independent variable)* to see the effect on behavior *(the dependent variable)*. An experiment is a **carefully designed study** in which one or more of the factors suspected of influencing the phenomena is changed and all others factors are held constant. If the observed phenomenon changes when a factor is manipulated, we say that the manipulated factor (the IV) causes the effect (the DV).

Good experiments meet three general quality criteria: **internal validity, external validity and reliability.** *Internal validity* means that the experiment was properly controlled and conducted with a sufficient number of randomly assigned test subjects, and actually demonstrates a cause and effect pattern. *External validity* means that the experiment gives information that can predict future equivalent situations. *Reliability* refers to the ability of others to repeat the experiment and get the same results (Santrock, 1997). Experiments can be fatally flawed when any of these three criteria are not met.

A single study usually doesn't provide earth-shattering or conclusive answers, no matter what gets announced by the media. Finding conflicting results about a particular topic or issue isn't unusual—in fact this pushes research to be conducted by more scientists whose investigations then give stronger support or evidence about the topic. A report of one research study should never be taken as the absolute, final answer to a problem.



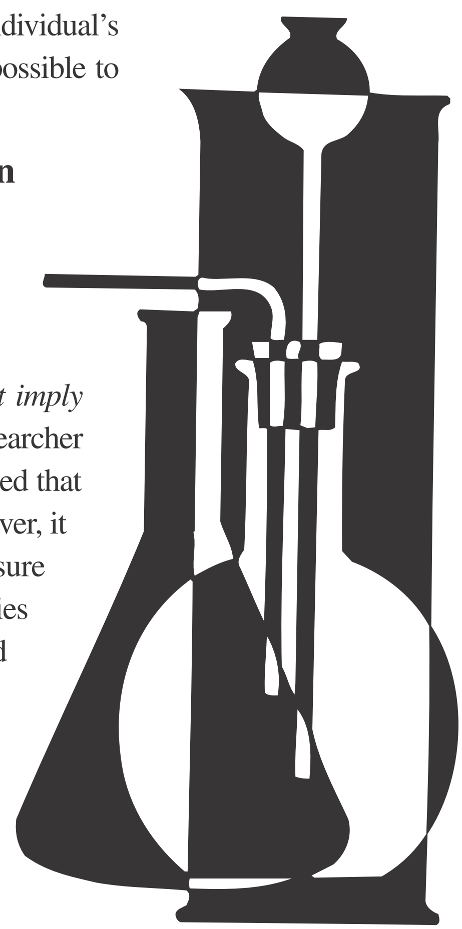
2. Descriptive Research: Limited Control Over External Variables

Sherlock Holmes scolded Watson, "You see but you do not observe." We look at things all the time, but casually watching everyday events is not scientific observation. For observations to be effective, we have to know what we're looking for, when and where we'll observe, how the observations will be made, and in what form they'll be recorded (Santrock, 1997). We must observe systematically, according to clear documented criteria. Scientists use three basic types of descriptive research; *naturalistic observations, surveys,* and *case studies.*

In **naturalistic observation** scientists observe behavior in real-world settings and make no effort to manipulate or control the situation. An example is Jane Goodall's observations of chimpanzees in Africa, where she recorded the behaviors of a group of chimps for many years. Animal populations in the wild are frequently studied by this method to determine what's normal behavior for that species. Scientists who study animal behavior are called ethologists.

Surveys are of two basic types, interviews and questionnaires. Sometimes the quickest way to get information from people is to ask them for it. Obviously, this type of study cannot be used for non-human subjects. In order to draw conclusions from interviews and questionnaires, a *random sample* that represents the group surveyed is a must. In a random sample every member of a population or group has an equal chance of being selected. The larger the group surveyed, the more reliable the data collected.

A *case study* is an in-depth look at a single individual. This method is used mainly by medical or psychological researchers when the unique aspects of an individual's condition cannot be duplicated. Since the subject is unique, it is not possible to generalize the research to other situations.



3. Correlational Research—Correlation is *NOT* Causation

In **correlational research,** the goal is to discover and describe the strength of the relationship between two or more events or characteristics. This is useful because the more strongly events are correlated (related or associated), the more effectively we can predict one from the other. However, a relationship between two factors *does not imply* one actually causes the other. Variables are *not* manipulated by the researcher in correlational studies, but can be measured. For example, it is observed that people with high blood pressure also suffer from high job stress. However, it would be a serious error to then conclude that the high blood pressure causes the stress. Drawing causal conclusions from correlational studies is one of the most common mistakes made by the media. To really find out if one factor causes another, experimental research must be used.

Is it Possible to Prove A Hypothesis? *and* Scientific Investigation: Terminology and Concepts

Timeline

10–20 minutes, depending on if reading and/or writing is first assigned as homework.

WIC-R Strategies

- Writing
- Inquiry
- Collaboration
- Reading

Concept Statement

Students will be introduced to more in-depth information on why it is not possible to prove a hypothesis with absolute certainty. They will also continue to develop their scientific vocabulary relating to experimental design.

Lesson Plan

This activity can be done early in the semester as students are learning about experimental design and have completed other preliminary activities about the nature of science.

1. Duplicate Student Handouts, "Is it Possible to Prove a Hypothesis" and "Scientific Investigation: Terminology & Concepts" and have students read both either in class or for homework (preferred).
2. Ask students to write for one minute (during the last five minutes of a class session) in their InterActive Notebooks on whether it's possible to prove a hypothesis. Call on individual students to read what they have written. Do not make judgments about the content, just ask students to read. Tell them they will do some further investigation and writing on the question.
3. For homework, have students, using the strategies from Unit 3 to paraphrase the "Hypothesis" section. After checking for completion, have students review each other's paraphrases and critique them. You should collect these to review how well students are able to paraphrase. If any confusion exists about the concepts or students are having trouble paraphrasing, review the information.
4. Next, using the "Terminology" sheet (which students read for homework), have students devise in collaborative groups a strategy for remembering the vocabulary words (15 minutes).
5. Conduct a quiz on the vocabulary and hypothesis concepts. Hold students accountable to use the terms in their subsequent lab work.

Is It Possible to Prove a Hypothesis?

The short answer is, NO!

It is not possible to prove with absolute certainty and beyond doubt that a hypothesis" true." Why not? And if we cannot prove a hypothesis, what's the point of doing an experiment to test it?

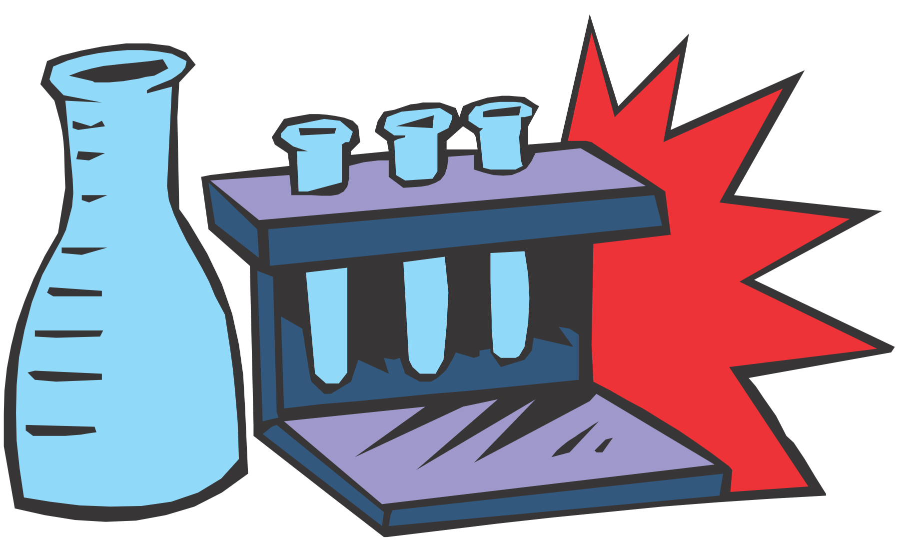
In any given experiment a hypothesis is developed, you make a prediction based on the hypothesis, and design an experiment to test the hypothesis. If the experiment results in data that agree with the prediction, then we can say that the hypothesis is *supported.*

It's possible the experimental results are consistent with other hypotheses that we haven't tested or even thought of. If we continue to make different predictions based on the original hypothesis and test these, we can test the hypothesis in a variety of ways. If all the experimental evidence supports the hypothesis, then our confidence in the correctness of the hypothesis increases. At the same time, the possibility of another, better hypothesis decreases. **IF EVEN ONE OF THE EXPERIMENTAL TESTS DOES NOT SUPPORT THE HYPOTHESIS, THEN THE HYPOTHESIS MUST BE REJECTED AND IS DISPROVEN.** Then there must be another explanation (hypothesis) for the experimental results that we haven't yet considered. Sometimes, assumptions creep into scientific work, and weaken experimental results.

Assumptions are statements or assertions accepted as true without any evidence. They represent the weakest part of any experiment. Why are assumptions made if they can cause serious doubts about the interpretation of the data? Usually assumptions are made because checking them with further experiments would be very difficult or impossible. Sometimes assumptions go unrecognized, and these can cause serious errors. Unrecognized assumptions can cause investigators to neglect interpretations that could be good explanations or to overlook serious flaws in their experiments. When analyzing experimental designs and results, it is always essential to ask the following: *What assumptions are being made? How to these assumptions affect the interpretation?*

Scientists are constantly searching for tests to DISPROVE, not prove, hypotheses. If, with rigorous testing, the hypothesis continues to stand, our confidence in it increases. To make this process work, remember to do the following:

1. Search for *different predictions* and experiments to test the hypothesis.
2. Search for *alternative explanations* of experimental results. Other interpretations will suggest new ways to test the hypothesis.



Scientific Investigation: Terminology and Concepts

In your science classes, you will be required to *interpret experimental results, make predictions, identify assumptions,* and *evaluate experimental designs,* as well as design your own experiments.

1. An *investigation* starts with a specific question.
2. A *hypothesis* is a "best guess" answer to the question.
3. A *prediction,* based on the hypothesis, can be made that indicates what SHOULD happen under certain conditions if the hypothesis is supported.
4. The *prediction* is a guide to test the hypothesis; an experimental design clearly specifies how to conduct the experiment.
5. The *experimental design* controls all variables except one, the experimental variable (also called the Independent Variable, or IV).
6. The *results* of the experiment are the data from the experiment. This data is presented in the form of tables, graphs, and figures.
7. The *interpretation* explains the results; it tells what the results mean.
8. *Assumptions* made when analyzing the data should be identified, and, if possible, tested.
9. Investigators should look for *alternative interpretations* and consider as many as possible before deciding which one might be the best—based on the data collected.
10. Several predictions leading to different experiments should be made from the same hypothesis. If abundant data support the hypothesis, our confidence in the "correctness" of the hypothesis increases.

Adapted from R. Allen (1995). *Biology: A Critical Thinking Approach.*

“The AVID program provides students with powerful instruction and support networks to help them be successful. Within our district we’ve found that students who participate in the AVID program are eager and prepared to enter rigorous coursework while in high school.”

—Dr. Eric J. Smith, Superintendent of Maryland’s
Anne Arundel County Public Schools

UNIT 6: EXPERIMENTAL DESIGN AND LABORATORY INQUIRY

Overview

Goal: **The goal of this unit is to teach students how to construct an experimental design and refine the art of writing lab reports.**

Science students have been exposed to labs since, at least, middle school. However, if asked to design an experiment, many students are at a loss. If given the opportunity and instruction, students can quickly learn how to design effective experiments. When students understand the underlying structure of experimental design, they can more clearly interpret and analyze the results of these experiments. According to the College Board, science students should be able to

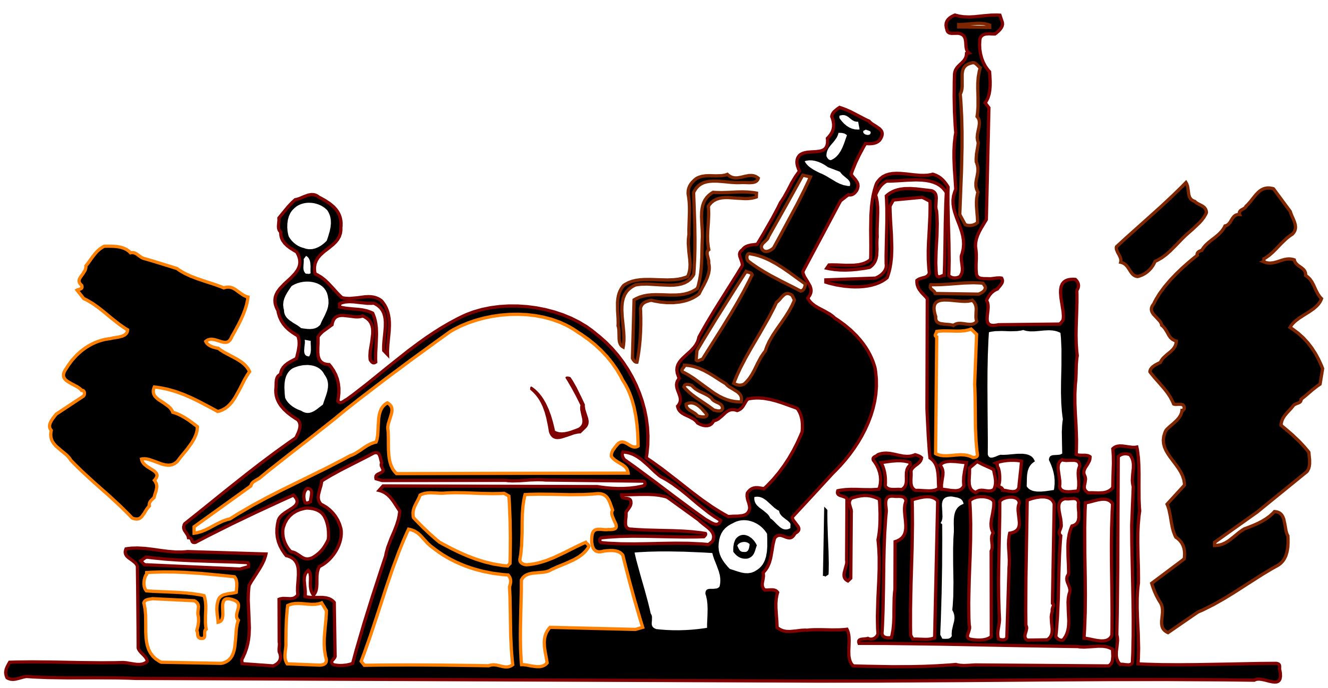
- design appropriate and testable explanatory models;
- critique experimental designs;
- understand the importance of appropriate controls in experiments;
- practice identifying variables and recognizing the importance of changing only one variable at a time when conducting experimental procedures;
- practice predicting the outcome of an experiment and comparing the prediction to the actual outcome; and
- acquire an understanding of the logic of the scientific method, and the meanings of and distinctions between proving, disproving, and failing to disprove a scientific model.

Equally important, but frequently neglected, is the formal lab report. This writing activity is the staple of scientific communication. It is the one type of writing that is universally 'done' by scientists. The formal lab report is found in professional scientific journals. A quick glance at these journals will show all the parts of a lab report including background, hypotheses, experimental design, findings and analysis. When students practice this lab report format they, in effect, join the scientific community of learners. Teachers may fail to assign the lab report due to many concerns, including grading issues or lack of time. However, students must think deeply to write, and in order to produce a quality lab report, must spend quality time thinking about the lab work itself. Not every class lab activity is worthy of a lab report. However, labs in which there is an element of inquiry and student discovery are appropriate for lab reports.

In this unit, you are introduced to the teaching of experimental design using a design template with student friendly sequential steps called the *ExD (Experimental Design).* Students will practice these experimental design techniques in a *Design Experiments* collaborative activity. Following this activity, students will be expected to write *ExD's* as part of their regular lab work. Introduced next is the *Write Path Lab Report* format that details each part of the lab report. This *Lab Report* gives extensive student directions in order to train students in the critical elements of scientific writing. This is followed by two lab report rubrics; one for teachers and a peer grading rubric to help students review each other's work. The pages that follow in this unit provide student designed instructional support materials with explanations on how to complete each section of the lab report in a more detailed fashion. These student support materials can be duplicated into a lab packet for student reference during the year. Students will improve their understanding of experimental design and the quality of their written lab work when given clear instructions and models to follow.

California Content Standards Addressed

Investigation and Experimentation 1. a, b, c, d and j.



Experimental Design

Timeline

50 minutes to 100 minutes

WIC-R Strategies

- Inquiry
- Writing
- Collaboration

Concept Statement

If students don't understand how experiments are put together and designed, then they will not be able to do high quality lab work or deeply analyze the results from experimentation. Once students have been given a model, or *schema*, for how experiments are put together, they can apply this knowledge to all of their lab work. They can become increasingly confident in their abilities to design experiments and to understand why controlling the elements of an experiment is important to all high quality scientific work.

Lesson Plan

Since lab work is fundamental to build sound science concepts, this activity should be conducted early in the year, during the first or second week of school.

Day 1

1. Review the unit and reproduce the Student Handout pages and make the designated overhead transparencies.
2. Use the ExD vocabulary handout to review the terminology. Have students define each term. Using the Student Handouts "Experimental Design Template: Pre-Lab Preparation" and "Guide to Creating ExD" as templates to show students the different parts of the ExD format using direct instruction.
3. As a class, collaborate to develop an ExD for an experimental scenario. Examples include designing a lab to determine if the mass of an object affects its density and designing a lab to test which kind of pain reliever relieves a headache the quickest.

Day 2

Each lab team will need blank paper for their ExD's and sketches.

4. Put students in collaborative lab groups of 2–3 students. Hand out *Designing Experiments: ExD Practice.* Instruct students that they have 45 minutes to complete five (5) Experimental Designs as a group.
5. Instruct students to sketch the set-up for each scenario. Show the experimental design in ExD format. (Include a minimum of 4–6 constants that could effect the results.)
6. Call on each group to present their ExD designs for one of the scenarios to the class. Allow each group to demonstrate their ExD.
7. Grade in class or collect the five (5) ExD designs from each group and check for accuracy.
8. For all subsequent labs, have students fill out an ExD template PRIOR to beginning lab work. This can be assigned as homework before the lab, or completed in class before beginning the lab work.
9. To assess, check student ExD's prior to having them begin lab work. This only takes a few minutes and builds a culture of getting ready (mentally) for labs. The ExD is incorporated as part of the formal lab report, taken up

Sample: Guide to Creating an ExD

Title: The effect of water temperature on goldfish gill beat rate.

Must relate to the variables in the experiment *Step 10.*

Shows cause and effect *Step 9.*

Hypothesis: Goldfish gill beat rate will increase with increasing water temperatures.

Independent Variable (IV): Water temperature in ºC.

The cause—what is changed in the experiment *Step 2.*

(Steps 5, 6 and 7)

Experimental Groups	250 ml water @ 20ºC (control)	250 ml water @ 30ºC	250 ml water @ 40ºC	250 ml water @ 10ºC	250 ml water @ 5ºC
# of Trials (times repeated)	3	3	3	3	3

The effect. This is what gets measured *Step 3.*

Dependent variable (DV): Goldfish gill beats per minute.

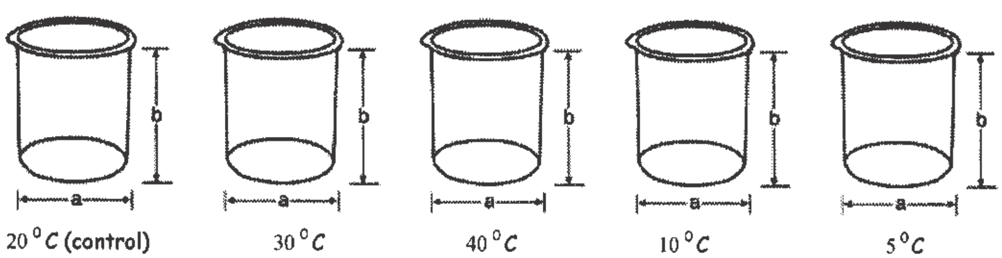
Control Group: Goldfish gill beat rate at room temperature (20ºC).

What the experimental conditions get compared to *Step 8.*

Constants *(Step 4):*

- Water amount in the beakers
- One fish used in each trial
- Same digital timer
- Same thermometer used
- Same counting method (clicker)

Experimental set-up sketch: 5 beakers with 250 ml water, 1 goldfish, water temp. as noted below *(Step 11):*



Adapted from: Cothron, J., Giese, R. & Rezba, R. (1989). *Students and research: Practical strategies for science classrooms and competitions.* Iowa: Kendall Hunt Publishing Company.

Experimental Design Vocabulary for Students

The following are explanations of the essential components of a valid experiment. Each of these components will be labeled on an ExD chart before an experiment is performed.

Independent Variable IV	"THE CAUSE" Must be measurable or categorized and manipulated by the scientist. This is the factor that the scientist changes directly.
Dependent Variable DV	"THE EFFECT" Must be measurable or categorized and is the result of the IV. This is the factor that changes because the IV causes it to change.
Title	This is the research question to which an answer is sought. Includes IV and DV. It can easily be phrased as "The Effect" of the IV of the DV.
Hypothesis	This is the prediction about the effect of the IV on the DV. It is based on information collected before completing the experiment. It proposes the specific way in which the IV will cause the DV to change. It can easily be stated as an "If/When..., then..." statement. Remember to state the hypothesis clearly.
Experimental Groups	The groups of the IV that will be tested are described. The control situation is labeled. There are two groups minimum and they are described based on how the IV changes.
Repeated Trials	Experiments are performed many times in order to average the data and minimize the chance that the results are a fluke. Science experiments must be done many times for credibility. Depending on the class time available, 1–5 times is appropriate. Five to ten times would provide more data and is indicative of a better experiment.
Control	The control group is the experimental group that gets no treatment or is the comparison group. All experiments have a control. Sometimes the control is the group that receives the recommended amount of the IV.
Constants	Every factor except the IV must remain the same in a experiment to be sure that the IV is causing the resulting change in DV. Experiments that have many constants are referred to as well-controlled. Constants stay the same. Be specific when referring to constants. Water is not an appropriate constant, while the same source of tap water is an appropriate constant.

Experimental Design Vocabulary for Students

The following are explanations of the essential components of a valid experiment. Each of these components will be labeled on an ExD chart before an experiment is performed.

Independent Variable IV	
Dependent Variable DV	
Title	
Hypothesis	
Experimental Groups	
Repeated Trials	
Control	
Constants	

Guide to Creating an ExD

1. Use the ExD template page provided (or make your own). Required ExD items are: title, hypothesis, independent variable (IV), a two row chart for the experimental conditions and number of trials, the dependent variable (DV), control group and constants.

2. Identify the **independent variable** IV and write it in the appropriate space.

3. Identify the **dependent variable** DV and write it in the appropriate space.

4. Identify all of the **constants** and list these in the appropriate space.

5. Determine how many different conditions of the independent variable you are going to test. Divide your two row chart into this number of columns.

6. Write a brief description of one group in the top row of the first column. Then write a brief description of the second group in the top row of the second column. Continue this until you have filled all of the top row boxes.

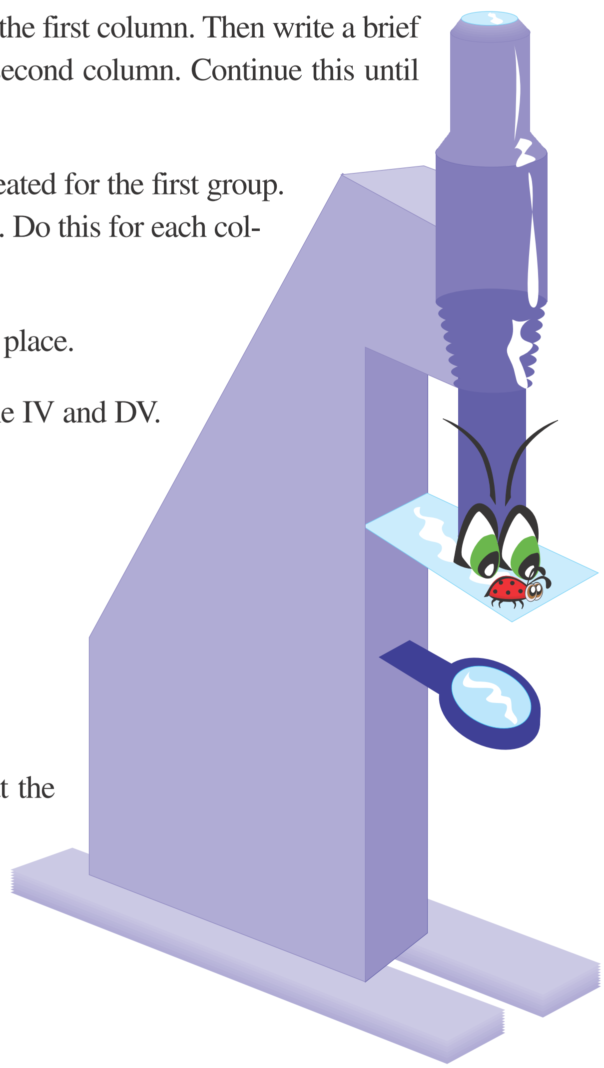
7. Determine how many times the experiment is to be repeated for the first group. Write this number in the second row of the first column. Do this for each column of the second row.

8. Identify the control group and write it in the appropriate place.

9. Write a hypothesis that shows a relationship between the IV and DV. Be sure it passes all four hypothesis tests (below).
   - **4 Hypothesis Tests**
     - — Does it show cause and effect?
     - — Does it lead to an experiment?
     - — Is it clearly stated?
     - — Can it be measured?

10. Now write a **title** that clearly and concisely states what the experiment will be investigating.

11. Complete an experimental sketch and label all equipment.



Experimental Design Template: *Pre-Lab Prep*

Complete this ExD planning form BEFORE beginning a lab

Name ______________________________ Date ______________

Lab TITLE: *(The effect of* ____________________ *on* ____________________).

HYPOTHESIS: *Use an if/when... then... statement. State the cause & effect relationship between the IV and the DV. The hypothesis must be testable.* ______________________________

____

INDEPENDENT VARIABLE: *What is the cause agent? What are you changing?* ______________

____

- *The number of columns will vary depending on how many testing conditions exist in the experiment.*

Experimental Groups				
# of Trials				

DEPENDENT VARIABLE: *(What is being measured?)* ______________________________

____

____

CONTROL GROUP: *(What is the experimental group being compared to?)* ______________

____

____

EXPERIMENTAL CONSTANTS: *(Variables not altered during the experiment)*

- ______________________________
- ______________________________
- ______________________________
- ______________________________
- ______________________________
- ______________________________

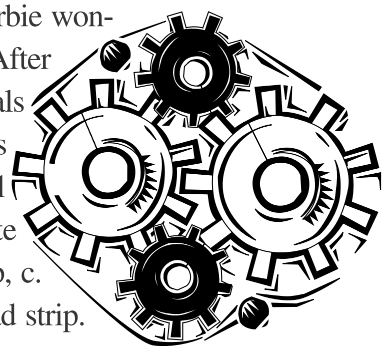
SKETCH OF EXPERIMENTAL SET-UP, clearly labeled: *(attach to this form)*

Designing Experiments: ExD Practice

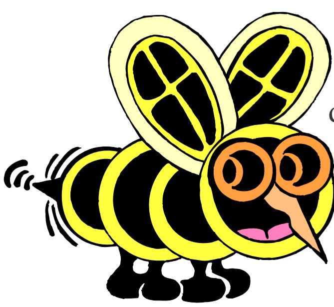
Directions: Sketch the set-up for each scenario. Show the experimental design in ExD format. (Include a minimum of six constants that would affect the results.)

Scenario #1: Reducing Rust

In the newspaper, Erbie Terbium read that a utilities company was burying lead next to iron pipes to prevent rusting on the pipes. Concerned that the lead could leak into the ground water, Erbie wondered if there was a metal that would be a safer metal that also prevents rusting. After conducting an initial experiment that determined the effectiveness of various metals in releasing hydrogen gas from hydrochloric acid, Erbie hypothesized that less rusting would occur with more active metals. Erbie recorded the mass of each nail before wrapping the nail with the metal. He placed the following into separate beakers of water: a. (1) iron nail, b. (1) iron nail wrapped with an aluminum strip, c. (1) iron nail wrapped with a magnesium strip, d. (1) iron nail wrapped with a lead strip. Each beaker held the same amount of water, the same mass of metals and the same type and size of iron nails. Five days later, Erbie rated the amount of rust as small, moderate or large, and recorded the color of the water. He also recorded the mass of each nail and found the difference in mass of each nail. The change in mass of the nail is the mass of rust formed.



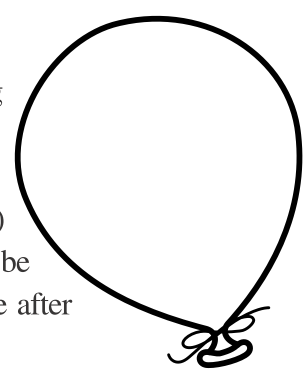
Scenario #2: Agitated Bees



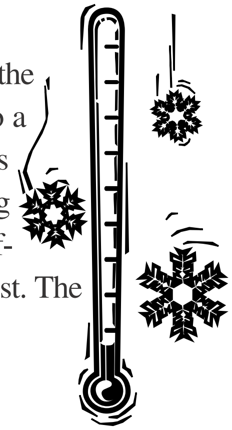
Ethyl Ene was attending a garden tea party when she noticed that some women seemed to attract more bees around them than other women. This caused her to wonder if certain perfumes contained chemicals that tend to agitate bees. After some background reading, Ethyl learned that many perfumes contain a particular organic compound referred to as Ester X. Ester X is known to attract and excite bees. Because perfume formulas are secret, she decided to determine if the unknown Ester X was present in four different perfumes (Confusion, Beware, Purple Hays, Elemental) by observing the bees' behavior. Joanna's procedure was as follows. She placed a watch glass containing 10 ml of the perfume 3meters from the hive opening. She recorded the time required for the bees to emerge and made observations about their behavior including the time it took bees to approach the watch glass. After a 30-minute recovery period, she tested the next perfume. She compared the bee behavior to a watch glass of 10 ml of distilled water. She repeated the procedure six times for each perfume.

Scenario #3: Weather Balloon Data

Sally Sodium is a superb scuba diver. She is extremely conscious of the increasing pressure as she dives deeper in the ocean. She decided to study what happened to the pressure on a weather balloon as it ascended into the atmosphere. Sally will rig a pressure sensor to ten weather balloons that will record the pressure in kilopascals (kPa) every 100-m as the balloon rises in the sky. The maximum altitude at which data will be recorded is 500 meters. Sally will release the balloons from McLean High School one after another on the same day.



Scenario #4: Depressing the Freezing Point



When making homemade ice cream, it is critical to add rock salt to the ice that surrounds the inner container of the ingredient mixture. The addition of salt, or any solute for that matter, to a solvent (like ice, the solid form of water) lowers the freezing point of the solution. This means that the mixture of salt and ice will have a temperature that is below 0˚C. The lower freezing point allows the ice cream to freeze. Ever the inquisitive chemist, Plut Onium tested which different solute added to the ice would change the freezing point of the resulting solution the most. The household solutes that he used were: rock salt, baking soda and sucrose (sugar).

Scenario #5: Soil Acidity and Germination Rate

A constant cause for concern in National Parks, especially during hot, dry years, is wildfire. Forests develop a great deal of dead plant material that dries up over time and will burn quickly and easily when the conditions are right. Wildfires are difficult to control and extinguish even when they are caught early. The damage to national parks, homes and the environment can range in the millions of dollars. However forest fires, while destroying land and threatening wildlife, bring life to several types of plant life. The intense temperatures of the wildfire flames cause certain seed coats to burst open. Only then can the seeds germinate and develop into a new plant. In an effort to prevent wildfires from starting and heating up to these extreme temperatures (wildfires are extremely difficult to extinguish), rangers set small controlled burns, aptly named managed fires. These fires burn less intensely (the seeds above cannot germinate at these temperatures) but serve to remove the dry brush and tinder, inhibiting future wildfires. The types of fire (wildfire v. managed fires) can affect the chemistry of the soil by altering the acidity. The change in acidity affects the growth of future plant life. Al Kane, a biochemist, is interested in the effect of fires on pine tree life cycles. As a preliminary study, Al will test the pH of soil that has been generated in each type of fire as well as soil that has not been exposed to fire. Help Al design his experiment.

Adapted from: Cothron, J., Giese, R. & Rezba, R. (1989). *Students and research: Practical strategies for science classrooms and competitions.* Iowa: Kendall Hunt Publishing Company.

Write Path Lab Report

Timeline

20 minutes to review with students. More time if you show models of student work.

WIC-R Strategies

- Writing
- Inquiry
- Collaboration
- Reading

Concept Statement

This writing activity is the staple of a technical scientific communication. It is the one type of writing that is universally 'done' by scientists. The formal form of a lab report is found in professional journals. A quick glance at these journals will show all the parts of a lab report. Students should learn how those practicing our discipline write and communicate their findings. When students practice this lab report format they, in effect, join the scientific community of learners.

Lesson Plan

Since lab work is an essential part of all science classes, this lab report format should be introduced to students early in the course.

1. Reproduce for students the *Write Path Lab Report* pages, including the "peer review" grading rubric, and make overhead transparencies of selected pages.
2. Using the *Write Path Lab Report* pages walk students through the different parts of the Lab Report using direct instruction.
3. An excellent way for students to 'see' how the lab report works is to provide a copy of a scientific journal article or several articles, one per group. Students will see an authentic product by practicing scientists, written in a formal, academic style. Have them go through the journal article and identify the parts of the lab report in small collaborative groups. Recommended journals include: *Nature, JAMA, Lancet, Science, American Biologist,* etc.
4. Ask the groups to report out on the different sections of the lab report in order and what the authors found or described. What gave them trouble in the text, if anything?
5. As a writing-to-learn activity, have student write about what they discovered in their InterActive Notebooks and how they might improve their own lab work.
6. To assess, using the Lab Report Rubric for grading is recommended. This rubric should be shared and clearly communicated with students prior to turning in their first lab report. One strategy is to have students peer review each other's lab reports using the *Peer Review Lab Rubric,* and then give students time to go back and edit their work prior to turning it in. Again, this type of writing requires higher order thinking and processing skills. It will be difficult for students the first few times. However, the increasing quality of student writing and understanding of science laboratory work is well worth it.

The Write Path Lab Report

In order to prevent unnecessary pandemonium in the scientific community, it was decided a long time ago that experimental results would be published in magazines called journals. Journals are published for everyone to read not just the privileged few. Each field and subfield of science has their own area specific journals. Some examples are: *Plant Physiology, Trends in Biochemical Science,* and *Journal of Evolutionary Biology.*

Most scientists subscribe to different journals to keep current in their field. This is how information is communicated most effectively. Publishing an article, however, is not easy. First of all, there are thousands of people trying to publish articles at the same time. If the article is not written in the right format, the publishers will not accept. **Appearance and format are very important.** Other articles are rejected because parts may be missing or the language is confusing. Just like journal publishers, *your teacher is very selective.*

A lab report includes the following sections in this SPECIFIC order: *If the sections are out of order, the work isn't taken seriously by the reviewers.*

- Title
- ExD
- Results
- Background Information & Works Cited
- Materials and Methods
- Analysis

How to Write the Title

The title, which is centered on the page, consists of a few well-chosen words **indicating the subject of the report** and it **MUST** indicate the cause and effect relationship tested in the lab. It is extremely important that you precisely describe the subject of the lab because when people are doing research on a topic, they often only see the title of the article or report. This is the only indication of the contents of the paper. They don't want to waste time reading a report that doesn't do what the title says it does. Refrain from using cute titles! **Sample title:** *The Effect of Visual Stimuli on Heart Rates in Adolescent Males.*

How to Write the Background Information

Begin this section with the section reading "Background Information" centered on the page.This section gives both the background of the experiment and the introduction to the experiment. It's important to research and **READ** about the topic of your experiment to collect this information. This section includes an explanation of the important facts about the general problem or area being investigated, explaining why this problem is of interest and outlining what information is already known. Use complete sentences. Citations are REQUIRED in this section. All sources used (textbook, articles, etc.) **must** be listed in your **"Works Cited"** section at the end of this section. Failure to do so is a serious offense—plagiarism, and will result in rejection of your lab report or worse. All of the sources used must be properly cited. For example, *The Loch Ness Monster is a Big Worm* (Molloy, 2003). See the Works Cited Guide in this section.

How to Write an ExD

Begin this section with the title ExD centered on the page. Refer to the "Guide to Creating an ExD" for the specific steps and format.

How to Write Materials and Methods

Begin this section with the section heading "Materials and Methods" centered on the page.

Materials: The materials are all of the equipment that you used to complete the experiment or lab. This is a comprehensive list. You can list them across the page using spaces between the items, down the page or in a two column list. For example. if you used 2 mg of salt, *you list 2 mg salt.* If you need 4 balloons, *then list 4 balloons.* This list should enable someone who is unfamiliar with the lab to gather all of the materials, then go their own lab and get to work. They should not have to go back for more stuff that wasn't on the list. Make sure everything in the **Methods** section matches what's needed in the **Materials** section.

Methods: This section of the report also includes a concise description of the procedures. **The methods clearly describe the experimental situation, the CONTROL situation and the type of observations you made.** There should be enough detail so that someone else could repeat your work. To make directions easy to follow, number each step sequentially like a recipe does. Finally, if you had to create any apparatus, you need to describe how to make it. It is **REQUIRED** to **sketch** the experimental set-up—one picture is worth lots of words! Label each sketch sequentially as Figure 1, Figure 2, etc. If you follow the procedure from a book or paper, just say so. You need not repeat them in your lab report. If you change the procedure, you should explain why you did so and exactly what you did differently.

How to Write the Results

Begin this section with the section heading "Results" centered on the page. Present your findings in a logical, not chronological, order. Give the results that you found, NOT what you think you should have found. You may have to do some thinking to find out why the results came out as they did. Do not explain your results in this section, the explanation belongs in the Analysis section which follows. Many papers are valuable for their correct results, even if the interpretation of the results is off base.

This section contains a collection of clearly **labeled (1) DATA TABLES, (2) GRAPHS and (3) FIGURES (drawings).** It also requires a *verbal description* about the data, graph or figure on the **same page** as the data table, graph or figure. When you present each table or figure, briefly describe important patterns pointing out trends or inconsistencies, but you should NOT include explanations or opinions. (See the Standards for Graphing).

Following the tables, graphs and figures is the **STATISTICAL ANALYSIS.** In this section show your calculations and/or your percentage error information. Remember to write a clear caption as to the results of the statistical analysis.

How to Write the Analysis

Begin this section with the section heading "Analysis" centered on the page. This is one of the **MOST IMPORTANT** sections of the Lab Report. Here you get to explain what the results of the experiment showed. In this final section you give **your interpretations** of the data and relate them to the questions you asked in the hypothesis section. Be careful to avoid just repeating the hypothesis section again. If you have any odd data to explain, do it here or make a new hypothesis as to why the results came out in a way you did not expect. Use the results section, both data table and graphs to support your statements. Read the following as a guide to make sure you have included this critical information in your analysis. The following items in a *well written* **paragraph** or two in the analysis section. Use complete sentences!

- What is the hypothesis you are trying to answer?
- Do the results answer your question?
- Do the data collected support or disprove you hypothesis?
- Use actual data collected from the lab to decide whether your hypothesis was supported or not. Carefully interpret the data you collected.
- What is the significance of your results on this topic?
- What problems during experimentation, or sources of error may have influenced your results?
- What further experiments should be performed to clear up discrepancies or vague areas in the results?
- How could your work be used by others or how could it be extended? What new hypothesis could be tested?

The analysis is an interpretation of the results of the experiment based on the data that you collected and the graphs that represent the data. **REMEMBER YOU HAVE PROVED NOTHING, MERELY *SUPPORTED* OR *FAILED TO SUPPORT* THE HYPOTHESIS.** Be sure to refer back to the objectives of the experiment. Include whether you accepted your hypothesis or rejected it based on your data. Present your conclusions clearly. **Write this section using complete sentences.**

Formal Lab Report Grading Rubric

Name ______________________________ Period ____________

Lab Title ______________________________

	Points Possible	*Points Earned*
Title Page	**Required or -5**	________
☐ Relates (IV) and (DV) in a serious scientific tone		
Background Information	**15**	________
☐ Describes background of the experiment		
☐ Describes the introduction to the experiment		
☐ Includes and explanation of the important facts about the subject being investigated		
☐ Explains why the problem is of interest		
☐ All sources listed in “Works Cited”		
Experimental Design (ExD)	**20**	________
☐ Title relates IV and DV		
☐ Hypothesis relates prediction about effect of IV on DV		
☐ IV and DV correctly identified		
☐ Describes experimental groups accurately		
☐ Tells how many times experiment is run		
☐ Control group is clearly described		
☐ Constants are specific and could realistically affect the results (minimum of 4)		
Materials and Methods	**20**	________
☐ Comprehensive list of equipment and chemicals used		
☐ Quantities and volumes are indicated		
☐ Step-by-step instructions for repeated procedures used to collect data		
☐ All materials are mentioned in instruction list		
☐ Labeled sketch of experimental set-up is provided and referenced		
☐ Explains exactly what data to record and when to record it		
Results	**20**	________
☐ Data Table(s) clearly labeled and neatly constructed including averages		
☐ Graph(s) clearly labeled and neatly constructed		
Analysis	**20**	________
☐ Hypothesis accepted or rejected		
☐ Interpretation/explanation of data using specific data from Results section using averages		
☐ Importance of results (refer to purpose of experiment)		
☐ Sources of error in experiment/factors beyond your control		
☐ Proposes new experiment and hypothesis related to this experiment		
Content and Style	**5**	________
☐ Well written with style/clear, varied sentences/well researched		
☐ Uses expository style		
☐ Report is formatted correctly		
	Total Points Earned	________

________ **Revisions are required (up to 70% credit can be earned)**

Peer Review: Write Path Lab Report

Purpose

This peer review is an opportunity to get help with your lab report before it is graded. You and a classmate will exchange lab reports. Read your partner's report and mark off the critical elements that he/she has done correctly in the lab report. This list of items serves as a checklist to make sure you have included everything in your lab report.

Instructions

Check the items that have been satisfactorily completed.

Format

- ☐ All sections have been attempted and are in the correct order
- ☐ Report is printed neatly in ink or typed on a computer or word processor
- ☐ Data Tables appear on their own pages
- ☐ Graphs appear on their own pages

Title

- ☐ Location of title is centered
- ☐ Title is the same as ExD title

Background Information

- ☐ The reading "Background Information" is centered at top of page
- ☐ Discusses purpose of the experiment
- ☐ Describes how this experiment will illustrate a scientific concept using the related major terms
- ☐ All material is directly relevant to the scientific content
- ☐ Cohesive writing style
- ☐ Well-researched using quality sources
- ☐ Works Cited entries use correct APA style

ExD

- ☐ The heading "ExD" is centered on the top of the page
- ☐ Title section accurately describes experiment relating IV & DV
- ☐ Hypothesis section
  - — Predicts the IV affecting the DV
  - — Is a reasonable prediction
  - — Sets up this experiment
  - — Uses If/when... then... format if appropriate
- ☐ Independent Variable IV section
  - — Is quantitatively measurable
  - — Is what experimenter changes
  - — IV is correct
- ☐ Condition/number of trials rows
  - — Top row needs to describe experimental groups
  - — Needs a minimum of 3 experimental groups
  - — Bottom row needs to state how many repeated trials
- ☐ Dependent Variable DV section
  - — Is quantitatively measurable
  - — Is a result of IV
  - — Is something that changes
  - — DV is correct
- ☐ Control section
  - — Control group is correctly identified
  - — Control is comparison point
- ☐ Constants section
  - — List at least 4 constants
  - — Lists specific environmental constants (ex. amount of sunlight)
  - — Constants that are controllable

Materials & Methods Section

- ☐ The heading "Materials" is centered at top of page
- ☐ Is a comprehensive list
- ☐ Includes the quantities of equipment
- ☐ Uses command words
- ☐ Uses expository style
- ☐ Includes a numbered set of step-by step instruction
- ☐ Is repeatable, complete and explains how to control constants
- ☐ Steps are well organized
- ☐ States how to collect measurements
- ☐ States when to collect measurements
- ☐ Describes how to set-up equipment
- ☐ Sketch in neat and labeled
- ☐ Directions refer to sketch
- ☐ Directions refer to all materials listed

Results Section

- ☐ Data Table(s)
  - — Has accurate title that describes what is in data table
  - — Uses ruler for straight lines
  - — Has row headings
  - — Has metric units in row heading
  - — Has column headings
  - — Has metric units in column heading
  - — Data is to be legible
  - — Includes averages in table
  - — Has summary sentence that explains what the results are
  - — Summary statement appears under table
- ☐ Graph(s)
  - — Uses graph paper
  - — Is as large as possible
  - — Has accurate title
  - — IV is plotted on x-axis
  - — DV is plotted on y-axis
  - — Has x-axis label
  - — Has x-axis units
  - — Has y-axis label
  - — Has y-axis units
  - — Graph type is appropriate
  - — Uses average data
  - — Uses data from results
  - — Line graph dots are connected from left to right
  - — Uses color appropriately
  - — Has a key for graph
  - — Summarizes the graphed data and the statement appears below x-axis
  - — Graph type is appropriate

Analysis Section

- ☐ The heading "Analysis" is centered at top center of page
- ☐ Explains purpose of lab
- ☐ States hypothesis
- ☐ States whether hypothesis is rejected/disproved or accepted
- ☐ States interpretation of the data, referring to collected data
- ☐ Explains these results based on knowledge of topic
- ☐ States sources of error and variables out of your control
- ☐ Proposes new experiment based on the results
- ☐ Provide answers to other analysis questions (if required)
- ☐ Is well written in a well organized paragraph form

UNIT 7: LABORATORY INVESTIGATIONS

Overview

Our intention in this section is to present a variety of labs and activities that promote the skills students need in the Advanced Placement science courses. It is not intended to be a complete series of labs required for success on the AP Exam. AP classes often focus more on the content of the course rather than how to learn the content. The College Board has prescribed the labs that need to be completed in each science course in *Advanced Placement Program Course Description* available on http://apcentral.collegeboard.com/courses/descriptions/1,3061,151-162-0-0,00.html. The labs presented here focus on using the skills discussed in units 1–6 to enhance student learning in science. As a result, students will enrich their lab experience and gain more understanding of science when they learn at deeper levels.

Differences in AP Science Courses Expectations From *Advanced Placement Program Course Description*

There are now four AP Science offerings: Biology, Chemistry, Physics and Environmental Science. The College Board intends that each course provides a rigorous lab component to demonstrate the experiential nature of science. Each exam tests this lab component with a rigorous question. However, the requirements of each course differ widely. AP Chemistry, for example, has 22 recommended labs. The exam usually has one question that focuses on one lab. Students must usually explain how to collect data including units given a list of equipment, manipulate the units of the data, analyze potential errors and determine percent error. This question not only requires specific content knowledge but also general science process skills. AP Biology has 12 recommended labs. AP Physics is different yet, with no recommended labs but a lab question that entails purely process skills.

A Word About Assessment

In this section, the variety of activities does not lend itself to one type of rubric. Some activities are based on correct answers while others have rubrics that delineate points to correct parts of answers. Still others have more holistic rubrics that classify answers based on the completeness and support of an answer. The variety represented here is indicative of the AP exams in science. Each exam and each type of question makes different demands on students. In Chemistry, the quantitative section rewards points based on showing work to solve a problem and using a calculator to get the answer. Points are taken away for the wrong number of significant figures. You earn points for the correct units. Later in the test, students must answer prompts with explanations based in chemical principles. In some questions you must not only explain why something is the way it is, as well as why it isn't another way. You must address all parts of the question to earn full points. Simply stating definitions will not earn a 5, the top score on the exam. Students must learn to read questions and answer them as completely as possible in a clear and concise fashion. This way, they earn all the possible points and have a chance to finish all of the questions. Again, these skills are important in all science disciplines. The necessary skills of effective reading and writing must be introduced and reinforced to our students at all levels of science.

A Word About Safety

This idea behind this section is to present activities that require students to use analytical thinking to learn at deep levels. Based on the more open-ended approach to science that is presented in these activities, we cannot present all the safety precautions that a lab manual might. We recommend that you review the safety procedures with your students for each activity, that you are or become knowledgeable about the chemical you choose to employ through these activities and that you conduct the activity first before using it with your students.

A Word About Use of Activities

The activities presented here are intended to provide ideas for labs and activities that require a high level of thinking and output from students. The scope and sequence of each activity may fit in naturally in your curriculum as presented or may need modification to meet your needs.

California Content Standards Addressed

Unit 7A

Biology/Life Sciences: Cell Biology 1.a and c, 4. c, 5. d and e

Biology/Life Sciences: Physiology 9. f

Investigation and Experimentation 1. b, c, and l

Unit 7B

Chemistry: Atomic and Molecular Structure 1. a and b

Chemistry: Chemical Bonds 2. a, c and h

Chemistry: Conservation of Matter and Stoichiometry 3. b, d and e

Chemistry: Gasses and Their Properties 4. a and c

Investigation and Experimentation 1. b, c and l

Unit 7C

Biology/Life Sciences: Ecology 6. b and c

Biology/Life Sciences: Evolution 7. a

Biology/Life Sciences: Physiology 9. b

Investigation and Experimentation 1. b, c, l and m

Unit 7D

Physics: Motion and Forces, 1. a, b, c and h

Physics: Conservation of Energy and Momentum 2. c and h

Physics: Heat and Thermodynamics 2. a

Physics: Electric and Magnetic Phenomena 5. a, b and c

Investigation and Experimentation 1. b, c, e and l

Activity 7.1 (1 of 4) *Teacher Guidelines* **(1 of 2)**

Fighting the Stomach Acid Blues

AP Discipline

Biology or Chemistry

Timeline

45–90 minutes

WIC-R Strategies

- Writing
- Inquiry
- Collaboration
- Reading

Concept Statement

Students investigate pH (and different methods to measure it) by designing and carrying out their own lab to answer the question about which antacid is "best." This activity combines several strategies to link together critical thinking, lab skills and acid base content knowledge.

Notice that this lab uses two methods to test pH: Universal Indicator solution and pH paper. Part of the intent of this lab is that students realize their results are dependent on the accuracy of measurement, which is directly influenced by the data gathering tool they use. The types of conclusions that they can draw, again, are conditional (see Unit 5) and subject to error. One of the students' tasks is to identify the sources of error—a very important part of doing science. Another interesting topic to explore in this activity is experimenter bias. Most students assume that scientists have none, but this lab highlights how bias is part of the human condition. Students may get varying results due to their interpretation of the color (and therefore pH) of the Universal Indicator solution. Again, this emphasizes the uncertainty of experimental results (and why it is important to pool class data) to find some verification of the results.

Lesson Plan

This lab is appropriate when studying pH, acid base reactions, or human biology (digestive system).

Teacher Prep

Gather the materials per lab team as listed on the student handout "Fighting the Stomach Acid Blues." Duplicate the student handout, one per student. It is a good idea to bring in some supplementary reading material or promotional product ads for students to expand their background knowledge. These materials can be used as either a pre-lab activity, or post-lab to help deepen their knowledge about this topic. The textbook alone may not deal adequately with this topic or with the questions students may raise after completing it. *Suggestion:* Search the web for appropriate material.

Teacher Guidelines (2 of 2)

Pre Lab

1. Before beginning the lab period, conduct a brief discussion about the three antacids to be tested. Ask students what they know about antacids, and about these three products in particular. We recommend that you have students write about what they already think they know about the action of antacids, why people take them, and any additional information they 'know.' (This is an excellent 'left side' entry for the InterActive Notebook.) You may also explore which antacid brand they think is most 'effective' and why. (We suggest that advertising, family members, or personal experience may bias their hypothesis development. This can be linked, following the lab, to explore the topic of experimenter bias [refer to Unit 5]).
2. Require that students fill out an ExD template (see Unit 6) prior to beginning the lab and that students identify a clear hypothesis, the DV and IV, and the control groups accurately. Their hypotheses may vary, which is to be expected. There is not a "correct" hypothesis. Return the ExD's that need revisions or lack important ideas. Review ExD's before students begin to collect data. Review all student procedures with the class, including safety rules.

Designing a Data Table

Students often have difficulty designing data tables because they don't know how to organize the information they are trying to collect nor do they realize what is important information. In this lab, students need to attempt to design a table to organize their ideas. There are many variations but some key ideas are:

- All information is contained in one table.
- There are column and rows.
- Repeated trials are grouped together so that differences and similarities are more evident.

During Lab

Oversee groups completing their lab procedures. Discuss the various types of data. Have groups talk to each other about their initial results. Have students record their individual lab group data on the board, and then record the class data on their data tables.

Post Lab

Model a sample calculation for the class using the class data. Use the median (not the mean) of the data sets for each tablet, since the median will exclude the outliers and give a truer middle value. Have students follow the logic of the calculations and the implications for testing their hypotheses. Optional: *If your students know how to do "Box and Whiskers" have them also create stacked box plots to compare the three tablets.* Ask if there are other types of analysis (e.g., statistical) that could also test their hypotheses (extending the learning). Have students complete the calculations in lab teams and graph the data (bar graph). Following the calculations and graphing, discuss as a class the results that lab groups gathered. Which pH testing method do they think is more accurate? Have students write up their findings as per the instructions on the student instructions and turn in a formal lab report (see Unit 6) for this lab.

Safety Admonition

Students need to wear appropriate lab attire including goggles and aprons. Before allowing students to work with any chemicals, refer to the MSDS sheet for associated risks and safety concerns. Instruction as to safe use must accompany any new equipment and chemicals.

Fighting the Stomach Acid Blues

Americans spend many thousands of dollars yearly to neutralize excess stomach acid and fight acid indigestion. The ads claim these tablets "*soak up excess stomach acid*" in a matter of minutes, and that each product is the "BEST." NOW is our chance to investigate these claims by experimentation, and learn about pH, acids and bases at the same time.

Pre Lab

Fill out your ExD and get approval from your teacher before beginning the lab. Attach the ExD (with the teacher's approval) to your lab write-up.

SET UP YOUR DATA TABLE NOW (see sample on following page). You'll collect both lab team and whole class data.

Materials per Lab Team

- Three 400 ml beakers
- 1.0 M HCl
- Mortar & pestle
- Three stirring rods
- Universal Indicator
- Univ. Ind. color chart (provided)
- Distilled water
- Balance
- pH paper
- Antacid tablets (three different kinds)

Methods

1. Fill each beaker with 150 ml distilled water.
2. Add five drops of 1.0 M HCl (hydrochloric acid) to each beaker.
3. Add 10 drops of Universal Indicator to each beaker.
4. Record the pH of each beaker's solution by both pH paper and color of the Universal Indicator (see color charts below.)
5. Weigh and record the MASS in grams of each of the three antacid tablets.
6. Grind antacid tablets using the mortar and pestle and add to each of the beakers. Remember to clean the mortar and pestle after each antacid product.
7. Stir each tablet solution with a clean stirring rod until it dissolves. (5–8 minutes)
8. Record the pH of the resulting solution with both the pH paper and by the color of the Universal Indicator solution.
9. Make qualitative observations during the experiment. For example, which dissolves fastest, description of type of solution formed, etc.
10. Record your team data and add it to class data on the board.

Results and Calculations

Sample DATA	Maalox	Tums	Rolaids
Color of solution before adding tablet			
pH (Universal Indicator) before			
pH (paper) before			
Mass tablet in grams			
Color after tablet dissolved			
pH (Universal Indicator) after			
pH (paper) after			
pH difference (Universal Indicator)			
pH difference (paper)			

1. **Calculate the pH differences** for each tablet using the pH as measured by the Universal Indicator **and** the pH paper. *Note:* Do the calculations for both your individual lab team data and the class data. (Beginning pH - Final pH).
2. **Calculate the pH unit change** per gram of tablet, written as [Δ pH/gram]. Then rank in order the relative ability of each tablet to neutralize the acid in the beaker, using #1 for the best neutralizer, #3 for the worst. SHOW YOUR WORK.

   (*Calculation example:* A pH change of 2.5 and a tablet mass of 5 grams = 2.5 pH/5g = 0.5 pH change per gram. Therefore, the largest pH change per gram of tablet would be the BEST acid reducer!)
3. **Graph your results** using the median of the CLASS DATA only for each tablet. What type of graph would best show this data? *HINT:* Dependent variable is on the Y axis (Δ pH/gram). The independent variable goes on the X axis (each tablet type). Don't forget the title, and a brief conclusion statement explaining the graph.
4. **Lab Report:** Follow the lab report guidelines. Be sure to write several paragraphs and discuss the results from this lab in the analysis section, using both your individual and class results. Did each method of measuring pH produce the same results? Relate your specific results back to your hypothesis. Did you support your hypothesis or have to revise it? What sources of error may have existed during the lab that may have affected your data collection accuracy? Why might your results NOT be conclusive? How do antacids actually work in relation to pH? What would you now advise your friends or family about these tablets?

Universal Indicator Color Chart - Approximate pH Values

red = 4.0	yellow = 6.5	blue green = 8.0	dark blue = 9.0
orange = 5.5	green = 7.0	blue = 8.5	violet = 10.0

Oh, My Aching Stomach!

Timeline

45–90 minutes

WIC-R Strategies

- Writing
- Inquiry
- Collaboration
- Reading

Concept Statement

This lab is an extension of the previous lab, but is more open-ended and requires that students design their own experiment, collect and present results, and develop their own analysis without guidance. Since this is an "open ended" investigation, there will be a variety of ways that students select to solve the problem. Encourage this! This lab could be used as a "lab exam" so that you can assess students skills around lab techniques, experimental design and abilities to collaborate.

Lesson Plan

This lab ideally follows the previous one and can be used as a lab exam to measure both what skills the students have mastered and the content about pH, acids and bases, and/or human digestion.

Teacher Prep

1. Gather the appropriate materials as indicated on student handout "Oh, My Aching Stomach!" You will decide what brand of antacid will be *Pills-R-Us*. Using a generic drugstore brand that is not easily identifiable (and was not used in the previous lab) will make the experiment more authentic. You'll need several bottles of this antacid for the students.
2. Tell students this is a lab assessment, and do not offer any hints or "how to's."
3. Let students work collaboratively and turn in one lab report as a group.
4. Evaluate on quality of experimental design, collection and presentation of results, and quality of analysis.

Pre Lab

Collect the procedures and experimental design. Review each lab procedure for completeness, the experimental design, and safety precautions. Return any procedures that require major revisions. Groups must complete their revisions and get your approval before collecting data. (*Note:* You can have groups complete different labs or work as a class to design one lab that everyone completes.)

During Lab

Oversee groups completing their procedures. Do not offer help or how to's. Part of the goal is to encourage collaboration among the lab team. You will have to decide if lab teams can confer with each other.

Post-lab

If time allows, have the students de-brief their experiences and findings to the other lab teams. This can be an excellent way to practice "speaking to learn." Collect the group lab reports.

Safety Admonition

Students need to wear appropriate lab attire including goggles and aprons. Before allowing students to work with any chemicals, refer to the MSDS sheet for associated risks and safety concerns. Instruction as to safe use must accompany any new equipment and chemicals.

Oh, My Aching Stomach!

Pills-R-Us is a pharmaceutical company whose major product is an antacid medicine for people suffering from indigestion and related problems. The FDA (Food and Drug Administration) has asked your company for a complete report on the effectiveness and reliability of this product. As the newest scientists there, you are being called upon to help solve the problem and show your "stuff."

Problem

Design an experiment to determine the optimal pH environment for the most effective environment for antacid tablets. Consider carefully how your team will determine if the tablet is working well. Complete an Experimental Design (ExD) before doing any experimentation. Get approval to begin from the Chief Investigator.

In the report you submit to the Board of Directors of Pills-R-Us, include:

- An introduction (1 page background information about antacid).
- An experimental design (ExD).
- A list of materials used.
- A procedure with sequential numbered steps.
- Results (data tables and graph(s)
- Analysis of results and implications

Materials available to your team: beakers, samples of *Pills-R-Us* antacid tablets, graduated cylinders, 1.0 M HCl, 1.0 M NaOH, distilled water, balance, stop watch, mortar & pestle, stirring rods, hot water bath, ice water bath, thermometer, wide range pH paper, and Universal Indicator. Other materials available on request.

Document both qualitative data (observations, sketches, color changes) and quantitative (numerical) data in clearly labeled data tables. Graphs should be used to help interpret the quantitative data and should be clearly labeled.

Analysis: Restate the problem and summarize the data found. How did you measure the degree to which the antacid tablet worked? Did the data support the hypothesis? What sources of error may have influenced the data?

To be eligible for a promotion on this investigation, the team must include an application to real life and answer the following in the background and analysis sections:

- What causes indigestion? What are some of the symptoms?
- How/why do the tablets help relieve the symptoms?
- Would these tablets relieve indigestion symptoms? Under what conditions? What evidence supports this?
- What side effect may result from taking these tablets, if any?

Compile the report, with a **cover page** listing all team members and submit for evaluation by ___________.

Leaf Stomata Investigation

AP Discipline

Biology and Environmental Science

Timeline

90 minutes

WIC-R Strategies

- Writing
- Inquiry
- Collaboration
- Reading

Concept Statement

This is an exploratory lab in which students can develop a testable hypothesis, collect specimens in the field, carry out their experimental design, collect and present data and analyze their results. This lab can also be used as an assessment of student microscope and lab skills. The variety of stomata types by plant species is truly amazing and many students find this to be a remarkable visual experience, one not shown in typical textbooks.

Lesson Plan

Fits well with a unit on photosynthesis or botany, after students have some content knowledge of the process of plant respiration and photosynthesis.

Teacher Prep

Obtain materials listed on the student handout. **Important:** Obtain a very cheap clear nail polish. You'll need at least 10 bottles for a class of 35. Use only clear cheap tape. **Do not** use the more expensive "magic" or "transparent" tapes that are cloudy under the microscope. Have unlined paper available and colored pencils for students to record their drawings. Have passes ready for lab teams (depending on your school policy) to go outside and collect samples. Be sure to tell them it's inappropriate to collect tree branches or to demolish the school plants for one or two leaves. If the weather does not permit outdoor collection, bring in leaves from houseplants or flowers.

Pre Lab

1. Review the lab directions with the students.
2. Have students fill out an ExD template before beginning the lab work (on Day 2). Make sure they have a testable hypothesis (one on the list, or another of their choosing) before they leave class on Day 1.
3. The greatest difficulty students seem to have with this lab is identifying what a stomata looks like—it's a good idea to show a model (or to have a picture in their textbooks available.) This is why a "skill check" is embedded in the lab instructions. On Day 1, you can demonstrate the technique while students give you the directions, or have a team of students come up and demonstrate for the class.

Activity 7.3 (2 of 4) *Teacher Guidelines* (2 of 2)

4. Instruct students on the importance of making accurate drawings as well as identifying the power of the microscope lens, their observations, etc. These drawings are "data" for this lab and for biologists. Many students don't think of recording what they see under the microscope as "data."

During the Lab

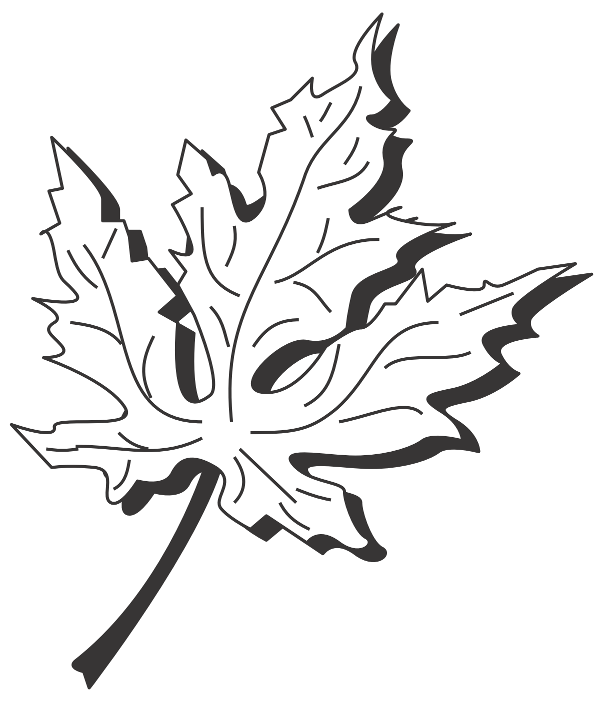
Walk around the classroom and check students' microscopes once they think they are looking at stomata. Students will have many questions; refrain from answers as much as possible. They will begin to rely on their own powers of deduction and problem solving in their collaborative lab teams. Encourage this behavior.

Post Lab

Discuss as a class the results that lab groups gathered. You can have each group report out on a poster their hypothesis and findings and have lab groups walk from poster to poster. Or, you can verbally discuss as a whole class and have a recorder take notes on a poster. You can chart findings or experiences, including data collection problems, common to the class. Have students write up their findings as per the instructions on the student lab instructions.

Safety Admonition

Students need to wear appropriate lab attire including goggles and aprons. Before allowing students to work with any chemicals, refer to the MSDS sheet for associated risks and safety concerns. Instruction as to safe use must accompany any new equipment and chemicals.

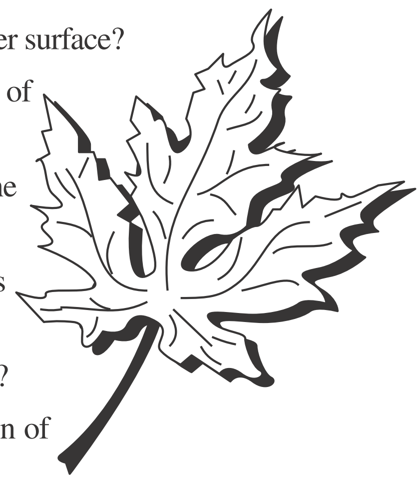


Leaf Stomata Investigation

You will demonstrate your mastery of laboratory skills by making your own leaf stomata slides, utilizing the microscope and designing an experiment. Begin by completing an Experimental Design (ExD) with your lab team.

Sample experimental questions: Use one from the list or propose your own.

- Do the number of stomata per field of view vary with the size of the leaf?
- Do the number of stomata per field of view vary from the upper to lower surface?
- Do the number of stomata per field of view vary based on the position of the leaf on the plant? (north, south, east, west)
- Do the number of stomata per field of view vary with the age of the leaf?
- Do the number of stomata per field of view vary in the same species from tree to tree? (or shrub to shrub?)
- Do the number of stomata per field of view vary between plant species?
- Do the number of stomata per field of view vary with the pigmentation of the leaf?
- Do green stems have stomata? Do the number of stomata per field of view vary from the leaves?
- Propose your own study question or combine elements of those above.



Directions for Making a Leaf Stomata Impression

A quick and easy method for making slides to measure the stomata of plants in order to investigate the diversity of stomata in plant species.

Materials

- Glass slides
- microscope
- blank paper
- various fresh leaf specimens
- clear transparent tape
- microscope slide labels
- colored pencils
- clear fingernail polish
- graph paper
- paper towel

Methods

Select your leaf; put it on your table with the **underside up.** Gently dust off any dirt or debris, using a paper towel. If the leaf happens to be wet, make sure to dry it before continuing.

1. Paint a small area of the underside of the leaf with clear fingernail polish. Make sure to keep the painted area small, about 1–2 cm square. Use as little of the fingernail polish as possible, since a thin layer dries faster and produces a better impression than a thick layer of polish.

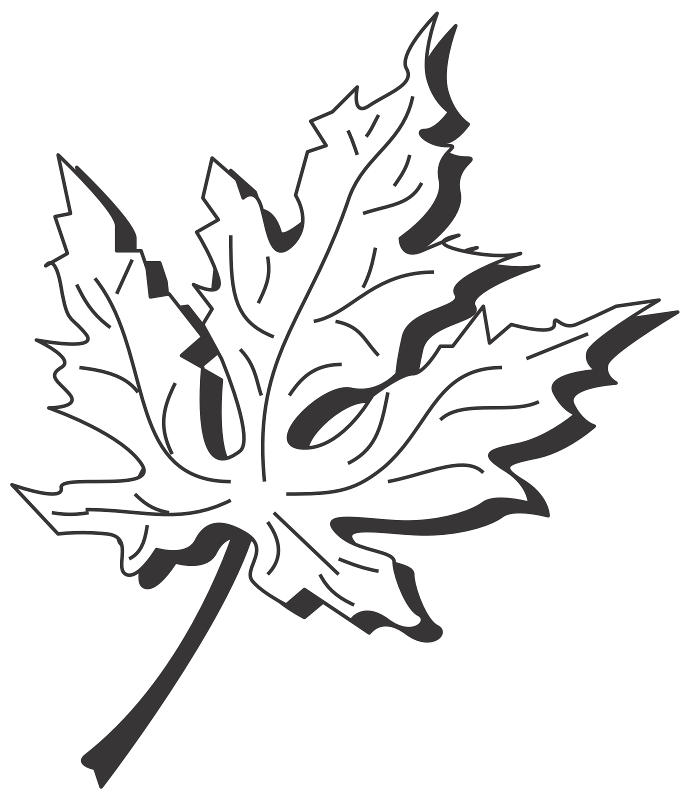
2. While the fingernail polish on the leaf is drying, label a slide with your name, date, and the type (species) of leaf sampled.

3. After the nail polish has **dried** (3–5 minutes), take a 1–2 cm long piece of clear tape. Holding the tape sticky side down, press it onto the nail-polished spot on the leaf. Rub your finger gently over the surface of the tape to make sure that it is stuck to the polish. **CAREFULLY peel the tape away from the leaf.** The fingernail polish should come away with the tape. Place the tape on the labeled slide and smooth it out carefully with your finger. Flatten out any air pockets to remove them.

4. Examine your slide with a microscope—begin with low power. Increase power as necessary. Identify the stomata and **get a SKILL check** from your teacher. CONDUCT the EXPERIMENT you have designed above. Collect data in tables you design. Make observations and drawings as you proceed. Label all drawings accurately.

5. Write up your experimental results and submit one group lab report following the guidelines. Don't forget to include all observations, microscope drawings (with power noted), data tables, graphs, and analysis of the data collected. What were your findings? Be sure to make a statement that answers your experimental question based on the evidence you found. What further questions do you have and what type of experiment could begin to answer them?

6. Produce a poster to share with the class that includes your hypothesis and findings. Be ready to present your poster to the class.



Osmoregulation in Goldfish

AP Discipline

Biology and Environmental Science

Timeline

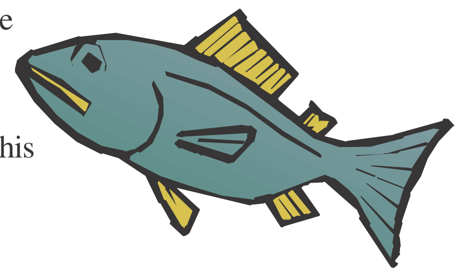
45–90 minutes

WIC-R Strategies

- Writing
- Inquiry
- Collaboration
- Reading

Concept Statement

This lab provides a way for students to directly experiment with osmosis and osmoregulation in a living system. Many students find the concept of osmosis confusing and don't realize how fundamental it is to living systems. Text material is frequently dry, and the old dialysis lab is less than stimulating for many students. The goldfish is an amazingly hardy osmoregulator and is not seriously harmed from this experience, as long as the stated methods are followed.



Lesson Plan

Use during the Biology unit on osmosis and diffusion to solidify these concepts, or during a unit on estuaries in Environmental Science.

Teacher Prep

1. Obtain 50 feeder goldfish (small ones work well), depending on numbers of students doing the lab. You should NOT recycle the fish over several periods—they need time to rest and recover. Two small fish per lab group is recommended.
2. Prepare the 30 ppt (parts per thousand) salt solution by mixing 30 grams of salt in one liter of distilled water. This is your "sea water solution." Depending on the numbers of students, you will need several liters of this solution.
3. Make sure students know how to operate a digital balance. They must work quickly to keep the fish in water as much as possible.
4. Recording the mouth opening and closing can be challenging. Doing real field work with living organisms is difficult, which is part of the "ah-ha" of this lab.
5. Be sure to discuss the care of the goldfish, since they are living organisms. Inform students of the consequences for any behavior that intentionally leads to damage of the goldfish.

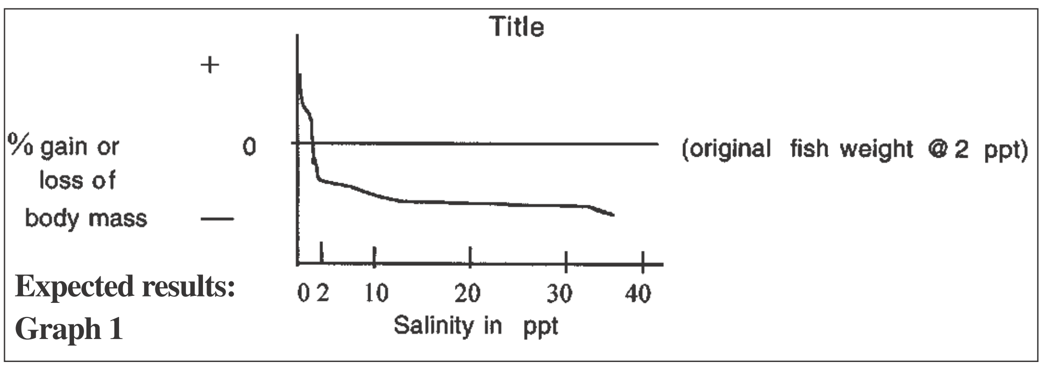
Pre Lab

1. Have students pre-read the lab and complete a team ExD the day before, during class. It's a good idea to give ExD approval during this time. They must arrive ready to begin the lab, so their data tables should also be ready the day before.
2. They should have background knowledge on osmosis and be familiar with the term "osmoregulator." You may need to review these concepts from the text or the background information provided in the student lab.
3. Make sure students understand that this is a living organism and deserves our respect and care.
4. Have student lab teams plan who is going to do what before they actually begin so that there will be little wasted time.
5. Have students record their team data on the board. All students must record the class data, derive the medians, and use it for the calculations and the analysis.
6. If some data appears to be skewed, ask students how we should deal with it; some groups may have practiced sloppy techniques and their data should be excluded.

During Lab

Make sure one lab team member gets the materials. Circulate through the lab groups and give directions where needed. Make sure students are "drying" the fish before massing it (both before putting in solution and after). Sloppy lab techniques will definitely skew the data in this lab, since the gains and losses of water are relatively small.

Post Lab



Expected results: Graph 1

Review the class data together. Look for outliers that indicate anomolous results. Question the lab groups about their techniques and decide as a class if the data should be included or excluded. If excluded, do not use it in the calculations. Determine the medians (not the means) of the remaining data sets and use these numbers for the calculations. Demonstrate (if necessary) how to do the calculations, or nominate a student lab team to come forward and demonstrate for the class. Students may need some help with the graphing and the interpretation. Discuss as needed.

Expected results: Graph 2 - varies greatly, but should reflect class results.

Safety Admonition

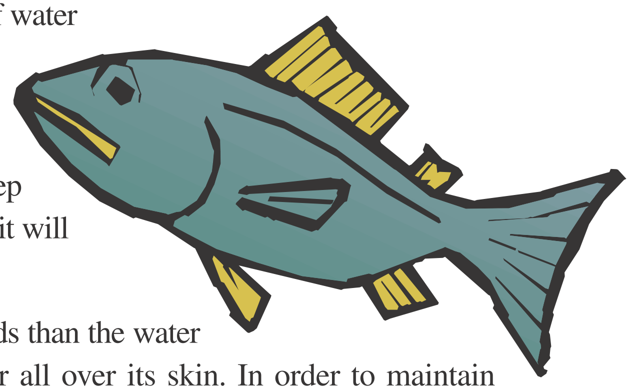
Students need to wear appropriate lab attire including goggles and aprons. Before allowing students to work with any chemicals, refer to the MSDS sheet for associated risks and safety concerns. Instruction as to safe use must accompany any new equipment. Additionally, discuss with students the safe handling of fish in the classroom by gently picking them up and setting them down, moving quickly through the lab in order for the fish to survive through the day. Students should wash their hands after the lab with soap and water.

Osmoregulation in Goldfish

Your lab team will construct an ExD, obtain materials to complete the procedure, collect data, and graph and analyze the results. Listen carefully to the rules!

Here's the background information - READ IT First!

Marine fish live in an ocean that is saltier than their body fluids. Water has a tendency to flow from the fish to seawater by osmosis. Osmosis, remember, is the movement of water across a semi-permeable membrane, like the cell. A marine fish continually loses internal water to its environment through the gills and mouth. In order to keep in osmotic balance, it drinks water, urinates little, and secretes salts to keep from drying out. If the fish fails to slow its natural water loss, it will become **hypertonic**, shrivel up, and die.



A fresh water fish on the other hand, has saltier body fluids than the water it swims in. Therefore, it constantly has an inflow of water all over its skin. In order to maintain osmotic balance, a fresh water fish drinks little, has a high urine output, and retains necessary salts with special cells. If the fish fails to slow it's natural water gain, it will become **hypotonic** and swell.

In this lab we are using a common fresh water fish, the goldfish. You will be placing this fish in three environments—its own aquarium water, distilled water, and salty water. By measuring its body mass, using a digital balance, you will be able to measure the percent water gain or loss by the living fish. The degree to which the fish can maintain internal osmotic balance will determine its change in body mass.

Materials

- 2 goldfish
- graph paper
- ruler
- 1 finger bowl
- blank paper
- 2 400 mL beakers
- digital balance
- salt solution (30 ppt)
- stop watch
- paper towels
- distilled water (0 ppt)

Methods

1. Construct an ExD for this lab. Start by determining the IV, then the DV, then the experimental groups. (Hint: read the methods!) Continue by including the constants and writing the hypothesis, then the title. There will be time for only one trial, so we will be sharing class data for the calculations and graphs.
2. WORK QUICKLY—Send one team member to get the materials at the front of the room. Put both goldfish in the finger bowl with their aquarium water (2 ppt). *Reread* the entire methods section again before beginning. Then, review your two data tables while the materials are being gathered.
3. Record all data IMMEDIATELY after the measurements are taken! You will be recording both **quantitative data** (numbers) and **qualitative data** (behavior).
4. Observe the two goldfish in their original aquarium water for about five minutes. Count the number of times the fish opens and closes its mouth per minute and record. Record its behavior also.

5. Tare a weigh boat on the balance. Carefully remove fish #1 from the finger bowl, rest it on the paper towel for about 15 seconds (to absorb excess water) and place it on the balance using the weigh boat. Record its weight to the nearest 0.01 gram. QUICKLY put the goldfish into the saltwater solution (30 ppt) in beaker #1. Begin timing with the stop watch when fish #1 hits the saltwater.
6. Watch fish #1 in the salt water solution (30 ppt) and observe and record its behavior. Count the mouth openings per 30 seconds, multiply by 2 and record as mouth openings per minute. **Leave the fish in the salt water for exactly 5 minutes.**
7. Gently remove the fish #1, rest it on a paper towel for about 15 seconds, and place it on the balance in a dry tared weigh boat. Weigh and record to the nearest 0.01 gram. QUICK... Place the fish back in the original fish-bowl water for a resting period of 5 minutes. Then... Count the mouth openings per minute—observe and record the fish behavior.
8. Remove fish #1 from the finger bowl, dry and reweigh using a tared weigh boat. Record the data. This is the fish #1's **recovery weight.**

Now... Repeat steps 3–7 for the second goldfish in DISTILLED water (0 ppt). Your lab team may chose to do this at the same time as the fish being tested in salty water. Once tested, take all fish back to the main tank, and proceed with the calculations. You will record your individual team calculations on the board for class data.

Calculations

Show all work! Each lab team member must know how to do the calculations.

1. To calculate % gain or loss use the formula below: *Note:* a "positive" answer means gain in water weight and a "negative" answer means loss of water weight due to osmosis.

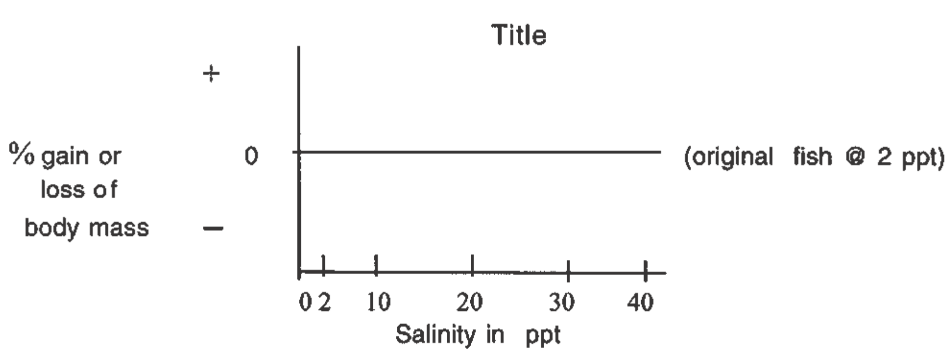
$$\frac{\text{(New weight - original wt)}}{\text{original weight}} \times 100\% = \%\ \text{gain or loss}$$

- Determine the % gain or loss of weight for fish #1 and fish #2. Record in your data table and on the board for the class data analysis.
  - — Use the class data (median) for the graphs below.

Graphs

Don't forget titles and conclusions!

0. Graph the salinity vs. % gain or loss. Use 2 points for the line graph—one point for the fish at 0 ppt (distilled water), one at 30 ppt (salt water). Assume that the % loss or gain is the same for all fish in the goldfish species. (See example)



1. Graph the mouth openings per minute DV (Y axis) vs. salinity IV (X axis), using a bar graph and the median of the whole class data.

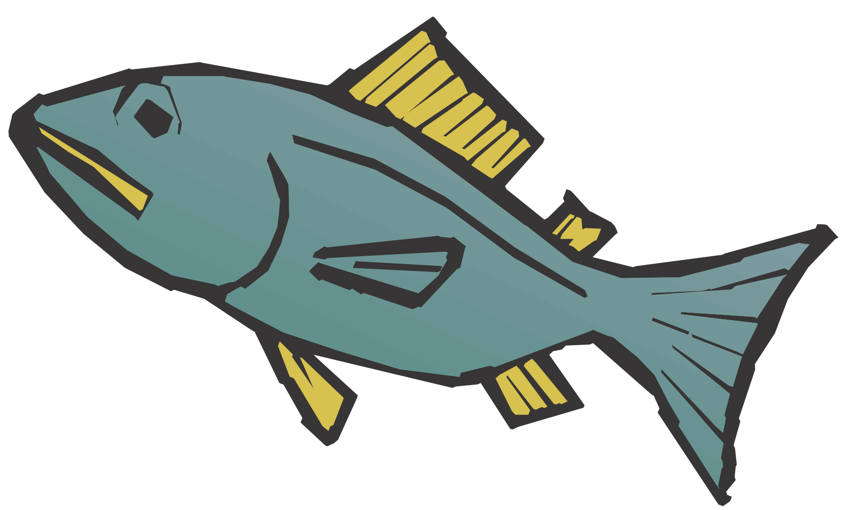
Data Analysis

Include a discussion of the following... Each lab team member must write his/her own and include it in the final report.

In paragraph format, discuss the results of the experiment. Was your hypothesis supported or not supported? Explain how the data you collected relates to the concept of hypertonic and hypotonic osmotic balance. Does the data indicate that the goldfish is a good or a poor osmoregulator? How do you know? Using the line graph, predict the % gain or loss of mass at 10% salinity and 20% salinity. What is the connection between water gain or loss in the fish's cells, and the type of water the fish is in? What fish behaviors did you notice as you moved the fish into distilled and salt water? Was there a connection between the mouth openings and the water type? Predict the range of salinity that a goldfish could survive in. Describe what kind of experiment you might do to determine this. What possible sources of error existed in this lab? What do you suggest we could do to correct them?

Turn in the Lab in this order.

1. Cover page with the lab title, a picture, and names of your lab team. PRINT clearly.
2. The ExD your team developed.
3. The data tables—clearly labeled—for your individual lab team and class data.
4. The calculations showing the percent gain or loss of water from your lab team for both fish, labeled clearly.
5. The two graphs with labels, titles and a summary statement.
6. The analysis paragraphs—each lab team member must write one.
7. Staple and turn it in.



The Paper Plasmid: A rDNA Simulation

AP Discipline

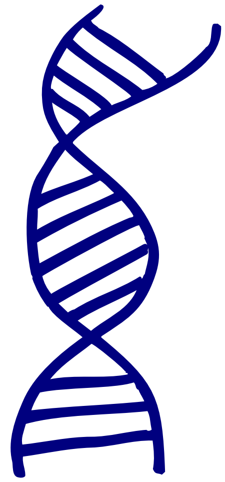
Biology and Environmental Science

Timeline

45–90 minutes

WIC-R Strategies

- Writing
- Inquiry
- Collaboration
- Reading



Concept Statement

This lab simulation provides a way for students to learn, in a paper model form, abstract terminology by manipulating the "players" of rDNA technology. Students are required to work in collaborative teams, put together human cell (linear) and plasmid (circular) DNA, and then use a series of restriction enzymes to cut the cell DNA 'gene' and insert it in the plasmid. From experience, jumping into the rDNA wet labs, without some type of concrete visual experience, keeps students from grasping many of the finer points of rDNA technology. Taking the time to allow students to practice the process on large paper models accelerates the learning during the wet labs that follow.

Lesson Plan

Use during the Biology unit on rDNA before beginning the transformation labs in the AP sequence. This can also be used in Environmental Science when you are addressing genetic engineering of plants or animals.

Teacher Prep

- Make copies of the required student lab instructions, one per student. Each student will need their own lab instructions, but teams just need one copy of the Cell DNA, Plasmid, and Rrestriction Enzymes handouts. Make copies of the Cell DNA, and Restriction Enzymes on two **DIFFERENT** colors of paper. Recommend the Plasmid handout be duplicated on white paper (antibiotic resistance areas will need to be individually colored by teams).
- Make available scissors, tape, and colored pencils. Students should have their textbooks available for reference.

Pre Lab

- Students should be familiar with the general vocabulary of DNA pairing, structure, and rDNA technology and should have completed some video, lecture, and/or text book reading on the topic prior to this exercise.
- Have students do some preliminary writing about what they know about rDNA technology in their Interactive Notebooks. The use of K-W-L chart is recommended (what I know, want to know, what I have learned).
- Preview the lab and go over the requirements (see student handout). It is helpful to show them your model of the plasmid.

During Lab

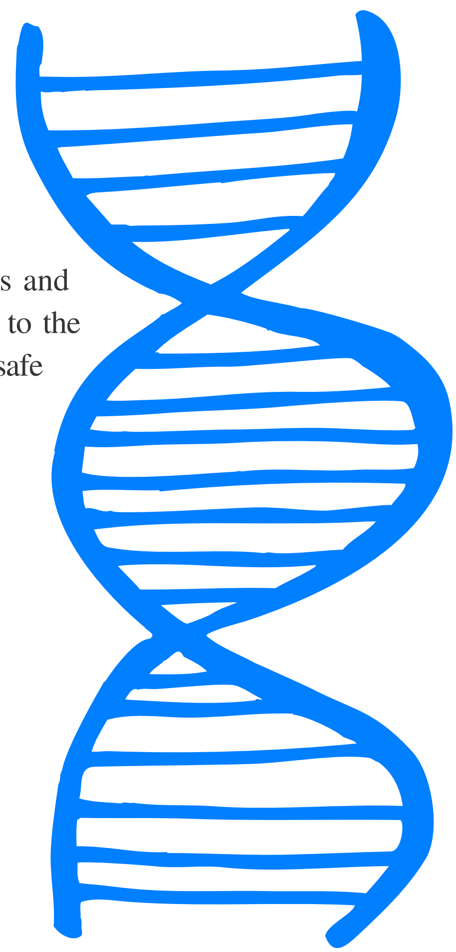
- Since this is a simulation with a problem to be solved, students may have lots of questions and show some frustration. Avoid answering questions that can be addressed through (1) reading the directions, (2) using their text for reference, and (3) using the combined knowledge of their lab team to problem solve.
- Make sure that students don't "cheat" by cutting random nucleotides to "fit" or reversing the direction of the nucleotides (violates the laws of nature). Students must use the given restriction enzymes to find the best fit—it is a challenge, but worth the effort. They are also instructed to keep the replication center and one antibiotic resistance area of the plasmid (which they sometimes "forget" about).

Post Lab

- Have students "show and tell" about the enzymes they used and how they went about the process of solving the problem.
- Measure the plasmid length by doubling over the plasmid and using a meter stick (shorter is better because it will have a greater chance of getting into the target cell and replicating).
- You can give rDNA "engineering points" for the shortest plasmid (or points for a range of lengths).
- Hold a post-lab discussion and then have students return to their K-W-L charts and reflect on what they have learned from this simulation. Share out, if time permits.

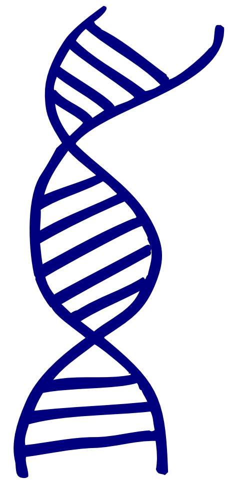
Safety Admonition

Students need to wear appropriate lab attire, including goggles and aprons. Before allowing students to work with any chemicals, refer to the MSDS sheet for associated risks and safety concerns. Instruction as to safe use must accompany any new equipment.



Paper Plasmids: A rDNA Simulation

Background



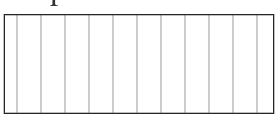
Recombinant DNA (rDNA) technology is fast becoming the new way to combat genetic diseases and to improve existing species of plants and animals. In this simulation you will investigate the way researchers use plasmids (circular pieces of non-chromosomal DNA found in some bacteria) to insert human (or other non-bacterial) genes into bacteria for replication in large amounts. Your team will use restriction enzymes, each of which cuts the plasmid at specific DNA base sequences. The place where the cut occurs is called a "sticky end." Any gene from any DNA can be inserted at a sticky end, *if it was cut with the same restriction enzyme.* (Activity adapted from unknown author.)

Methods

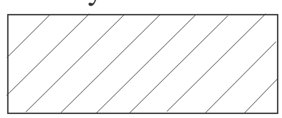
1. Obtain your "Plasmid DNA" handout (on white paper). Color the plasmid resistance areas with five colored pencils, one color for each of the following regions.

   KEY

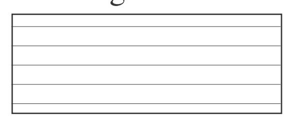
   Ampicillin resistance

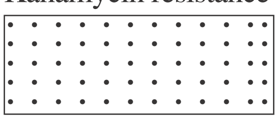
   Tetracycline resistance

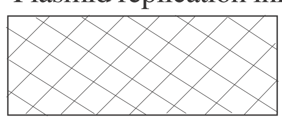
   Human gene of interest

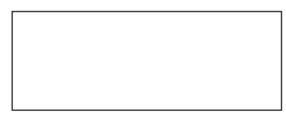
   Kanamycin resistance

   Plasmid replication initiator

   All other DNA

2. Cut the plasmid into strips along the dotted lines. Tape the strips together in the correct order to form a circle (numbers 1–6).
3. Obtain the human "Cell DNA" handout. Cut the DNA into strips and tape the ends together by matching the marked ends. *Note:* This DNA does not form a circle. The marked area of this DNA is the "gene" you want to insert into the plasmid. The rest of the DNA is just "junk" DNA (known as Introns), and you may use the restriction enzymes to remove as much of it as you want, **as long as you leave the entire "gene" intact.**
4. Obtain the "Restriction Enzyme" handout and cut out each restriction enzyme. Match the place(s) in order to pinpoint a location(s) in the human cell DNA where each of the restriction enzymes can cut. Mark these same matching locations on the back of the plasmid with the name of the restriction enzyme.

Now for the challenge! Here are the rules—read them carefully!

- Using whichever **two** of the restriction enzymes you want to use, cut the plasmid leaving at least **one antibiotic resistance gene** and the **plasmid replication initiation site** intact. You may cut out and discard "extra" plasmid DNA.

- Using the **same** two enzymes, **cut** the human cell DNA as close to the gene as you possibly can. Then splice the cut gene into the plasmid, where you have cut with the same restriction enzymes. *You will not get credit for this lab if the human gene is cut.*
- You may use a **total** of two restriction enzymes.

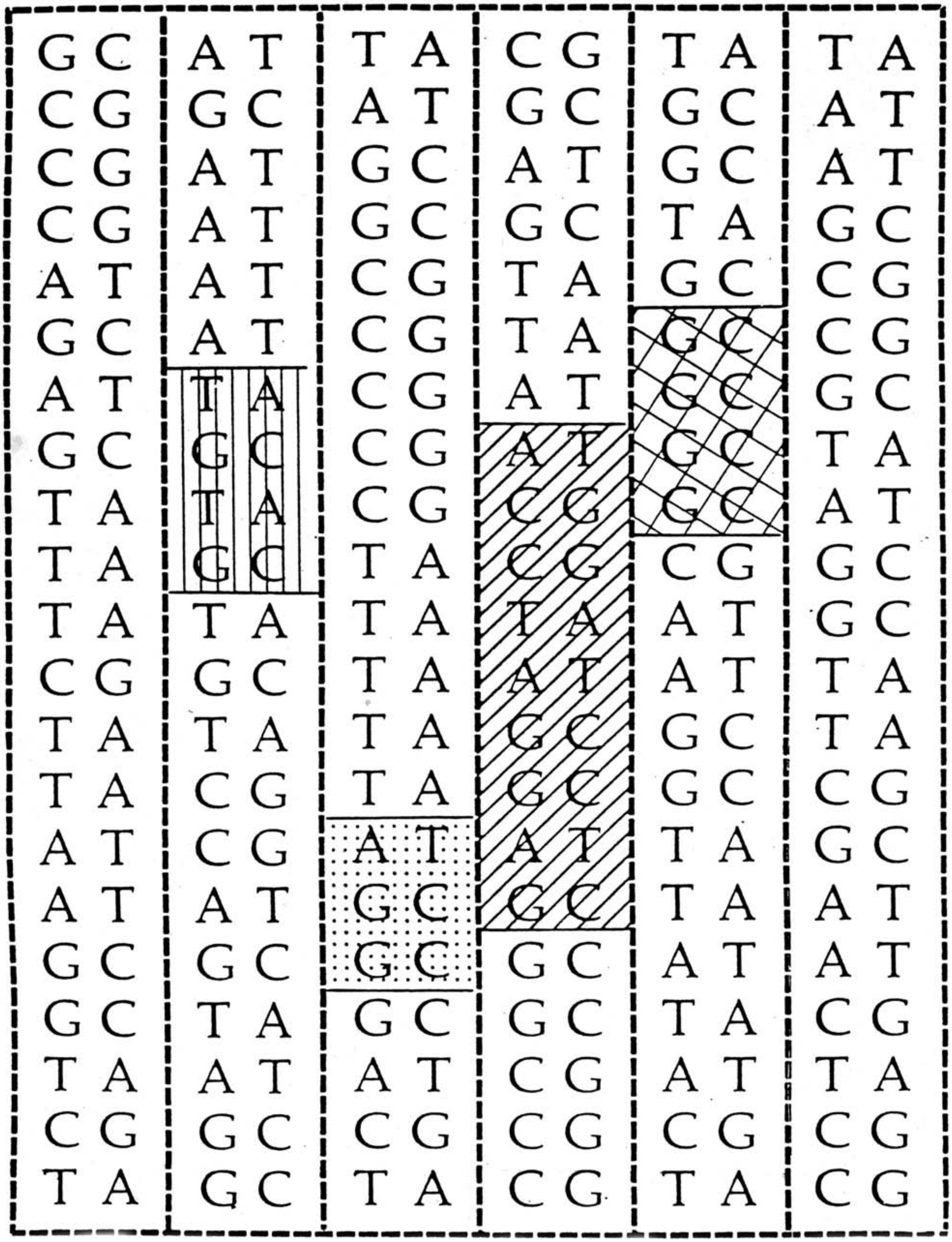
5. When you splice your gene into the plasmid, you must use a **LIGASE** enzyme to attach the "sticky ends" together. Also, tape the enzyme you chose to cut the DNA to the back of the plasmid's sticky ends. Use a RED colored pencil to indicate a ligase enzyme next to the restriction enzyme where the splicing has occurred.
6. A large part of your grade will depend on how short your final plasmid is. Assuming that your team followed all the directions (#1–6), teams with the shortest plasmid will get maximum points. Other teams' grades will depend on how much longer their plasmid is than the shortest one(s).

Paper Plasmid Analysis Questions

Each team members will answer these questions on another sheet of paper and submit by the due date.

1. What is the function of restriction enzymes
   a. in nature?
   b. in this simulation?
2. Once you have made a new plasmid with a human gene inserted, how does the human gene get amplified? (*Hint:* think of bacteria and remember that amplification means making copies. You may want to check your textbook, too).
3. Which two restriction enzymes did you use? Why were those chosen? What problems or issues did you run into as a genetic engineer?
4. How many sites on the human cell DNA would each of the two enzymes you used cut? How many sites on the plasmid DNA would each of the two enzymes you used cut? What inference can you make from this information?
5. Restriction enzymes are found naturally in bacteria. How do they protect a bacteria from viral infections? What protects the bacterial DNA from being cut by these enzymes? (Textbook time again).
6. Why do rDNA researchers need such a wide variety of restriction enzymes?
7. Why was it important to leave the following in the plasmid?
   a. one antibiotic resistant gene. Explain.
   b. the plasmid replication initiation site. Explain.
8. Think and research, then give an example of one human gene that could be spliced into a bacterial plasmid and relieve some current human disease or medical condition. Be specific as to your choice of gene and how it would help human health.

Plasmid

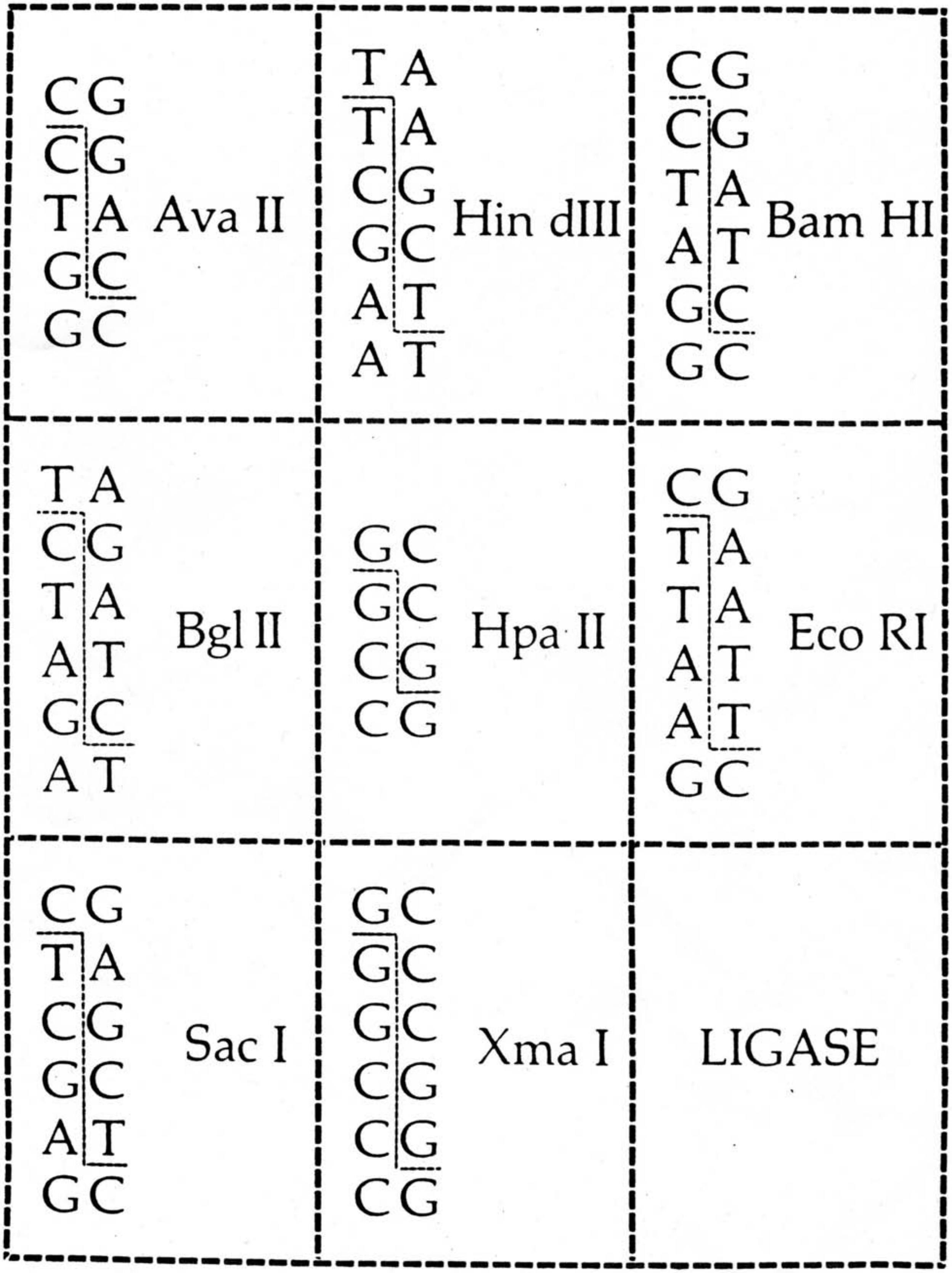


1 2 3 4 5 6

Cell DNA

T A	G C	T A	T A	G C	T A
G C	A T	T A	T A	T A	T A
G C	G C	C G	C G	A T	C G
G C	A T	G C	G C	A T	G C
C G	T A	A T	T A	T A	A T
C G	T A	A T	C G	A T	A T
T A	C G	G C	A T	T A	C G
A T	T A	G C	T A	T A	G C
G C	T A	T A	G C	C G	G C
G C	A T	A T	T A	C G	G C
C G	A T	C G	G C	T A	G C
A T	G C	A T	C G	C G	C G
C G	T A	T A	C G	C G	C G
A T	C G	A T	T A	T A	C G
G C	A T	A T	T A	T A	T A
G C	A T	C G	T A	A T	A T
G C	G C	G C	T A	A T	G C
C G	C G	T A	A T	G C	G C
C G	A T	C G	A T	A T	A T
C G	G C	T A	A T	A T	C G
G C	G C	C G	T A	T A	C G
1	2	3	4	5	6

Enzymes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Activity 7.6 (1 of 4) **_Teacher Guidelines_ (1 of 2)**

The Popcorn Lab

AP Discipline

Chemistry

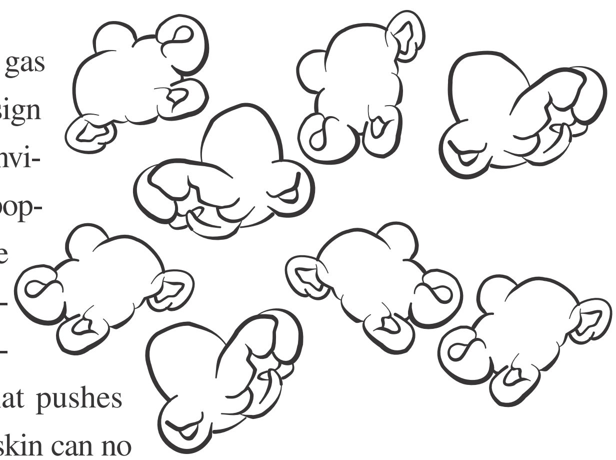
Timeline

Three 45 minute sessions (1 for pre-lab; 1 for data collection; 1 for starting to write the analysis)

WIC-R Strategies

- Writing
- Inquiry
- Collaboration
- Reading

Concept Statement



This lab, involving popcorn, is a fun way to introduce gas laws and phase changes to chemistry students. Students design valid, scientific experiments that investigate what internal environmental factors are critical to successful popcorn kernel popping. Through this lab, students learn that the water inside the popcorn is a critical component of popping power. The build-up of temperature causes the water to change phases from liquid into gas. This builds up pressure inside the kernel that pushes outward on the "skin" (the pericarp) of the kernel. When the skin can no longer hold up to the pressure, it explodes, cooking the endosperm in the corn and creating popcorn as we know it. Soaking kernels introduces more water and more explosive popping, while dry kernels do not pop well at all. The kernels with holes in the skin allow the water vapor to escape, reducing the build-up of pressure, resulting in a weak, if any, pop.

Lesson Plan

Teacher Prep

- Make copies of the Student Handout, one per lab team.
- Acquire enough popcorn for your classes (each group needs about 50 kernels). *For dry kernels:* Spread popcorn kernels flat on foil and allow to air dry for several weeks. Alternatively, use a drying oven on low heat, but watch that you don't pop the kernels. *For kernels soaked in water:* Place kernels in beaker of distilled water for several hours. Keep adding water as kernels soak to maintain that all kernels are covered. For punctured ker-

nels: Use a dissecting needle to poke three holes in each kernel of popcorn. **Alternate approach:** Have students complete these processes as part of their lab. This will help them ensure some of the controls in their experiment.

- Label a source for each type of kernel and set out for students. Put out equipment for students.

Pre Lab

Students must plan their experiment. Have them read a minimal amount about how popcorn pops: http://www.nasa.gov/audience/forkids/home/popcorn.html if they are stuck when designing their lab. Collect the procedures and experimental design. Review each lab procedure for completeness, the experimental design, and safety precautions. Return any procedures that require major revisions. Groups must complete their revisions and get your approval before collecting data. [*Note:* You can have groups complete different labs or work as a class to design one lab that everyone completes.]

During Lab

Oversee groups completing their procedures. Discuss the various types of data. Have groups talk to each other about their initial results.

Post Lab

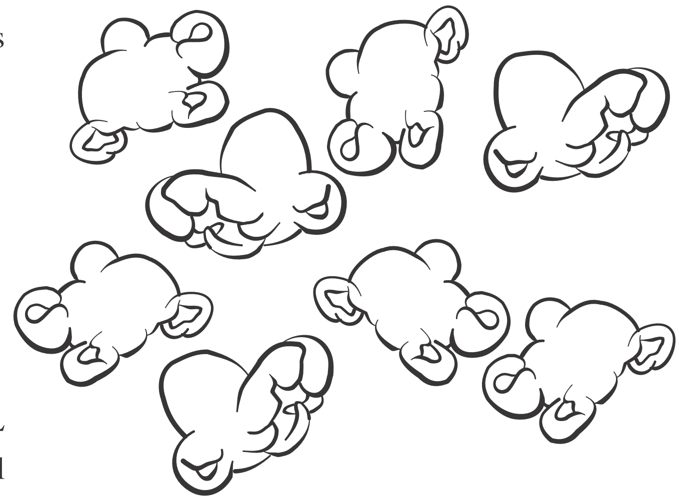
Discuss results as a class. Develop a theory that explains why the different popcorn kernels behave as they do. Have students graph their lab data and analyze the results according to the instructions on the student page.

Safety Admonition

Students need to wear appropriate lab attire, including goggles and aprons. Caution students that hot oil can cause severe burns and that popping corn can put out an eye. Students should also be careful when positioning pinholes in corn that they avoid their fingers. Instruction as to safe use must accompany any new equipment.

The Popcorn Lab

You will be observing the popping behavior of several modified types of popcorn kernels in order to understand how and why popcorn pops. The modified variations of popcorn kernels that you will have access to are:



1. dried in an oven over time,
2. soaked in water over time,
3. punctured with a pin several times,
4. unmodified, fresh popcorn.

Your popping apparatus will consist of a 50-mL beaker covered with aluminum foil that has 3–4 small holes pierced in the top. A Bunsen burner will serve as the heat source. Below is a list of equipment and materials that you will have access to.

Equipment

- balance
- 50-mL beakers
- Bunsen burner
- iron ring
- wire mesh
- 4 modified kinds of popcorn
- 1 dropper bottle filled with vegetable oil
- small piece of Al foil
- thermometer
- dissecting pin
- 5–6 kernels of each type of popcorn

Part I

With your lab team, design an experimental procedure to determine **how and why popcorn pops.** Carefully consider all factors that affect popcorn's reactivity as you consider how to design your experiment.

- What factors must be present in order for popcorn to pop?
- How will you measure those factors?
- How will you keep the testing procedure constant for each type of kernel?
- What will you measure?
- How will you change only one variable at a time?

- How will you be sure to collect data on the popping behavior of popcorn, not on the burning behavior of popcorn?
- With your lab partners, plan your experiment by considering all the factors of a valid, scientific experiment. (What is the IV? the quantitative DV? the qualitative DV?)

Think carefully what you want to test and then write a set of clear sequential experimental procedures that a 5th or 6th grader could read and successfully follow. Include all controls for your experiment in the procedure. Also create logical data tables to record all measurements and observations during your actual experiment.

Parts II and III

Get your procedure approved and collect your data. After completing your experiment, graph the results. Analyze the data. Use the following sets of questions to guide your analysis writing:

Paragraph 1: What was the purpose of this experiment? What was the hypothesis?

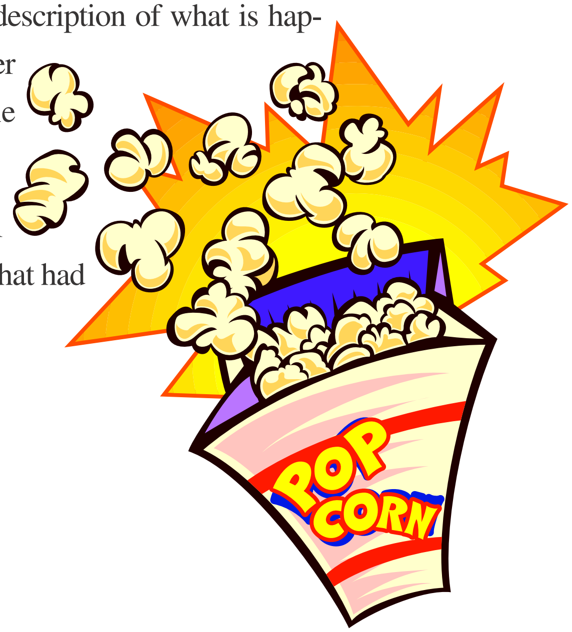
Paragraph 2: What did the results show about the popping power of each type of popcorn? Give actual mean averages. What did you observe about each type of popcorn as it was popping?

Paragraph 3: Were there any unexpected results? What were they and why were they unexpected? How are these results significant? What do they mean?

Paragraph 4: Based on your data and observations, explain what is necessary for successful popcorn. Consider the following: phase changes, how pressure is being created, and its effect on the popping process.

Paragraph 5: Explain how (and why) popcorn pops. Include a description of what is happening inside the kernel before it pops and as it pops. In other words, describe the environment inside the kernel and the processes that occur inside the kernel as it undergoes popping.

Paragraph 6: Extension: How would freezing the popcorn kernel for two days affect the popping? How would soaking kernels that had been dried out affect the popping?



Egad! The Crystalline Cube

AP Discipline

Chemistry

Timeline

90 minutes

WIC-R Strategies

- Writing
- Inquiry
- Collaboration

Concept Statement

The objective in this lab is to have students gather as much information about the mysterious matter (a sugar cube) before them in order to determine whether it is an element, compound or mixture. Students are required to design tests to gain insight into the makeup of the material through qualitative and quantitative observations. They are then required to classify each type of property and property change that they encounter. Finally the students report out their findings in a written report that draws a conclusion about whether this material is found naturally on Earth.

Most students will instantaneously recognize the alien substance for what it is (sugar). These students can also classify sugar as a compound given a list of materials to classify and explain what a compound is. However, this lab uncovers that students have a difficult time in articulating the definitions of elements, compounds and mixtures in their own words. This lab compels students to devise tests that help them to gather data about the substance as well as to determine what kinds of tests help them to learn the chemical versus physical nature of the material.

The analysis in this lab acts like an AP exam question because it requires students to answer multiple parts of the question. Students must explain not only why the matter is a compound, but also why it cannot be an element or mixture. Students who merely state the definitions of the terms will not earn the highest points because they have not applied the terms to the questions.

Lesson Plan

Teacher Prep

- Make copies of the Student Handout, one set per lab team.
- 10–15 sugar cubes are required per group.
- Determine and put out the types of equipment and reagents you will allow your students to use. For example: 1.0 M HCl, litmus paper, lime water, filter paper. In the case of special requests, either teach students to make these solutions or prepare in advance. Be prepared that once a group tries a unique test that other groups will piggyback. Make them do the test themselves or do a demonstration for the class. (It's better to let the students do the test if you can.)

Pre Lab

Review all student procedures. Return the procedures that need revisions or lack important ideas. These must be reviewed before students begin the collect data. (Photocopy Observation Quality Rubric.)

Designing a Data Table

Students often have difficulty designing data tables because they don't know how to organize the information that they are trying to collect nor do they realize what is important information. In this lab, students need to attempt to design a table to organize their ideas. There are many variations but some key ideas are:

- All information is contained in one table.
- There are column and rows.
- Repeated trials are grouped together so that differences of similarities are more evident.

Name of Test	Test Description	Classification	Observations	
		(Chemical, Intensive Physical, Extensive Physical)	*Quantitative (Measurements)*	*Qualitative (Descriptions)*
Ex. Mass of object	Place on balance	Extensive physical	8.00 g 7.54 g 8.10 g 7.94 g	White cube, grainy, about the size of index finger pad.

Completing the Tests

There are a wide variety of tests that students will develop given the time to do research. You need to be prepared to allow, or not allow, their tests based on safety, time and equipment restraints. For example, using gas chromatographs may not be feasible in your setting. Perhaps you do not want students to use concentrated sulfuric acid to react with the cube because you do not have a fume hood. Perhaps a student wants to use a barium compound that your district has banned for health hazards. You must decide what you will, and will not, allow students to do. Be prepared with your reasons. There are many ways to study the cube. Some ideas are: determine size, volume, mass, density, malleability, hardness, ductility, reaction to acids, reaction to bases, reaction to heating, reaction to cooling, solubility, melting point, when burned does it release CO_2, to name a few. It is important that you try to help students to determine the tests that are most effective in determining whether this type of matter is an element, compound or mixture as students often loose sight of this goal.

Post Lab

Discuss as a class the results that lab groups gathered. You can have each group report out on a poster and have lab groups walk from poster to poster. You can verbally discuss and have a recorder take notes on a poster. You can chart findings common to the class. Have students write up their findings as per the instructions on the student instructions.

Safety Admonition

Students need to wear appropriate lab attire including goggles and aprons. Before allowing students to work with any chemicals, refer to the MSDS sheet for associated risks and make the decision whether students can complete that test. Instruction as to safe use must accompany any new equipment and chemicals.

Egad! What's That Crystalline[3]?

Statement of Problem

An alien craft landed on Earth. As one of the "doors" of the craft opened, out fell this strange piece of matter, the crystalline cube. It is, heretofore, unidentified or classified on Earth. Because we know that you are one of the most thorough and complete chemists around, the city council thought that you would like to take this astounding opportunity to describe this new matter!

First, you must determine and describe its properties. Be careful! We have no idea where it came from or what it is. Additionally, please advise about the status of this matter as element, compound, or mixture. *Use all possible safety precautions. (Hint: No flame will be used in this lab because we don't know if the cube is flammable and safety is of great concern.)*

Hints from Mendeleev

- Think of the various properties that you can observe easily and complete those first (Example: describing the crystalline cube using the ideas you have learned).
- **Do not taste the sample.**
- Once the sample is destroyed, you must discard it.
- Develop procedures that could lead you to discover more properties.
- Complete all tests with approval from your instructor.
- Classify all changes as physical or chemical.
- Classify each property as chemical or intensive, physical or extensive physical.
- Use and manage your time wisely.

Materials Available

- Aluminum foil
- Distilled water
- Hydrochloric acid (HCl)
- Balance
- Watch glasses
- Others by advance request
- Hot plate
- pH paper
- Sodium hydroxide base (NaOH)
- Limewater (test for presence of CO_2 in gases)
- Cobalt chloride paper (test for H_2O in gases)

Procedure (20 points)

Prepare a complete procedure for each test that you plan to conduct. You must name the test and give a detailed explanation for completing the test. This must be a repeatable set of directions to someone who is not familiar with your lab set-up.

Data Collection (40 points)

Record all data on the table you design. It must include a name for the test, clear description of or procedure for the test, property classification, all observations and measurements that result from the test. You might start by massing the samples. You must develop as many other tests as possible in the time allotted. Be complete but concise. You will be evaluated on the quantity (minimum 10) and quality of the tests you perform. (You earn one point for each valid property test and one point for correct property classification. You can earn two points for each observation based on the quality. See the rubric.)

Lab Work (10 points)

You can earn points by working responsibly and making a positive contribution to your group. At the conclusion of the lab period, you must clean your station by the time indicated by your teacher to earn your clean-up points.

Analysis Section (30 points)

Prepare a written report and interpretation of your results (about the identity of the crystalline cube) to present to the City Council. Be sure to include:

- Identify sample as element, compound or mixture? Support your conclusion using the data you collected.
- What evidence was there of chemical and physical change during the tests?
- Hypothesize that this material is found naturally on Earth. What properties would you use to identify it and why?

Use the rubric in preparing your answer for maximum number of points!

Egad! What's That Crystalline[3]?

	No attempt (0 points)	Poor (1–4 points)	Satisfactory (5–6 points)	Good (7–8 points)	Excellent (9–10 points)
Classification of matter as element, compound or mixture	Does not classify matter	Incorrect classification or correct classification with no supporting evidence; omits discussion that eliminates two of the classifications	Correctly classified; states appropriate definitions of element, compound and mixture; does not explain why material is classified as student indicates; vague or no connection between definitions and classification	Correctly classified; some tests support the classification; includes appropriate definitions of element, compound and mixture; eliminates why not element or compound or mixture (Tenuous or mild connection between definitions and classifications)	Correctly classified; several tests support the classification; includes clear, concise, appropriate definitions of element, compound and mixture and applies these to their classification; eliminates why material is not element, compound or mixture (Strong connection between definitions and classifications)
Evidence of chemical and physical changes	Omits relevant discussion of types of change	Demonstrates no understanding of chemical and/or physical change	Explains each test; states definitions of physical and chemical change; presents evidence of physical or chemical change; connection between definition and data is vague or nonexistent	Explains each test; states definitions of physical and chemical change; presents evidence of physical or chemical change; connection between definition and data is vague or nonexistent	Explains each test clearly; states definitions of physical and chemical change; presents evidence of physical or chemical change; correctly classifies most changes
Identification of material	Omits explanation of properties for identification or explanation is not based on scientific information	Correctly identifies and explains minimal number of properties used for substance identification; somewhat reasonable hypothesis is based vaguely on lab evidence; explains why it could/could not be found on Earth	Correctly identifies and explains most properties used for substance identification; somewhat reasonable hypothesis is based on lab evidence; explains why it could/could not be found on Earth; vague connection between using certain properties to identify substances and presence on Earth	Correctly identifies and explains many properties used for substance identification; reasonable hypothesis is based on lab evidence; explains why it could/could not be found on Earth; strong connection between using certain properties to identify substances and presence on Earth	Correctly identifies and explains all properties used for substance identification; reasonable hypothesis is strongly related to lab evidence; explains why it could/could not be found on Earth; strong connection between using certain properties to identify substances and presence on Earth

Observation Quality Rubric

Scientists record information that describes lab or class activities as observations. Observations can be descriptive phrases or words and/or measurements. The quality of these observations will be evaluated based on completeness and quality of description. The following levels of quality are provided as guidelines for writing & self-evaluation of your own observations during lab and class activities. Each level of quality below will be awarded a certain number of points toward your grade. The number of points will vary according to the activity. Examples of each level will be presented in class and posted for student reference.

Superior Quality Observations demonstrate elaborate depth that describes as many observable qualities of the event as possible that are relevant to the work at hand (this may include but is not limited to color, odor, texture, clarity, formations of solids, evidence of reactions, etc.); excellent effort to record observations; clear description; and the event can be precisely pictured/mentally recreated based on recorded observations alone.

Good Quality Observations demonstrate sufficient depth that describes many observable qualities of the event that are relevant to the work at hand (this may include but is not limited to color, odor, texture, clarity, formations of solids, evidence of reactions, etc.); satisfactory effort to record observations; somewhat clear description of event and the event can be approximately pictured based on recorded observations and more precisely pictured with additional information from the lab documents.

Poor Quality Observations demonstrate little depth; describe few observable qualities of the event that are relevant to the work at hand (this may include but is not limited to color, odor, texture, clarity, formations of solids, evidence of reactions, etc.); show a minimal effort to record observations; unclear description of event and the event cannot be adequately pictured based on recorded observations.

Unacceptable Quality Observations demonstrate no depth; describe only one or two observable qualities of the event that are relevant to the work at hand (this may include but is not limited to color, odor, texture, clarity, formations of solids, evidence of reactions, etc.); show no effort to record observations; provide unclear descriptions of event and the event cannot be pictured based on recorded observations. One or two descriptive words are used.

Atomic Theory Lab

AP Discipline

Chemistry

Timeline

90 minutes

WIC-R Strategies

- Writing
- Inquiry
- Collaboration

Concept Statement

The AP test looks for students to make connections between concepts in chemistry. This lab has students determining the formula of a hydrate (a recommended AP lab) while trying to illustrate the law of definite proportions. While the lab is not a perfect application because the comparison is not between elements, it does demonstrate that there are fixed ratios for hydrates as well as elements within the compounds.

Lesson Plan

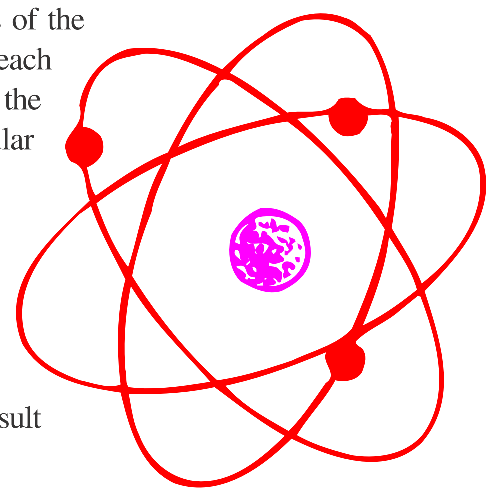
About the hydrate: You may feel free to select any hydrate you like or a series of hydrates time permitting. Copper (II) sulfate pentahydrate is named in this lab for its color change to mark the endpoint of the dehydration and because it does not decompose under these lab conditions. Consult a CRC and MSDS before using any chemical to ensure the safety of your students.

Pre Lab

Have students complete the pre-lab activities. After students have completed the pre-lab on their own, discuss their ideas as a class to highlight the idea that there are water molecules attached to the compound in a hydrate although the substance appears dry. Sketch the molecular view of a hydrate for students to visualize the compound association with water.

Post Lab

Have students answer discussion questions. You can collect these papers for grading or stamp them so that students may make notes and comments before they write their analysis of the data. Use Socratic questioning methods to help students to answer each other's questions. Avoid directly answering which law is supported by the data. Have students focus on what the data represents at the molecular level as well as in terms of atomic laws.



Safety Admonitions

Students need to wear appropriate lab attire including goggles and aprons. Before allowing students to work with any chemicals, refer to the MSDS sheet for associated risks and safety concerns. Instruction as to safe use must accompany any new equipment and chemicals. Consult your district guidelines on chemical use.

Atomic Theory Lab

Pre Lab: Define hydrate. ____

What is the formula of copper(II) sulfate?________________________________

Pre Lab

Copper sulfate is bonded to water when in the crystal phase. This is called a hydrate. By simple heating, the water molecules are liberated from the hydrate (they evaporate).

According to Proust's experimentation in the early 1800's, atoms combine in definite proportions by mass. This law can be extended to apply to molecules. In this instance, the same number of water molecules will be liberated from each copper sulfate molecule. The ratio of the amount of liberated water to the total mass of copper sulfate and water should remain the same no matter what how much material is used.

1. Preliminary observations of copper (II) sulfate pentahydrate crystals. Writing in complete sentences, record at least five qualitative observations. Make full use of available equipment including: microscope, balance, Bunsen burner. Draw two diagrams.
2. What substances from your everyday experience appear dry, but actually contain water? Work with your partner to compile a list of at least five substances. Give evidence to justify each claim.

Materials

- Scapula
- Clay triangle
- Iron ring
- Burner
- Balance
- Watchglass
- Ring stand
- Evaporating dish
- Tongs
- Hydrate

Procedure

Record all qualitative observations that seem relevant.

1. Record mass of evaporating dish and watch glass.
2. Add copper sulfate hydrate ($CuSO_4$) to an evaporating dish until it is approximately 0.5 cm deep. Record mass of evaporating dish, watch glass and copper sulfate hydrate. Calculate the mass of the copper sulfate hydrate. *Think:* you need to determine the mass of the copper sulfate only—no evaporating dish. How can you do this?
3. Place the evaporating dish on the clay triangle 5–6 cm above the Bunsen burner the cooler part of the flame. Then place the watch glass on the evaporating dish. Heat the copper sulfate slowly. In heating, the copper sulfate will gradually turn very pale blue or gray. If it begins to darken, you are heating it too fast, reduce the flame. If droplets form on cool parts of the evaporating dish, heat them and they will disappear.
4. When all the copper sulfate has turned pale blue, allow evaporating dish to cool and then mass the evaporating dish and copper sulfate residue. Record.
5. Reheat evaporating dish for 3 more minutes and allow to cool. Mass dish and watch glass and record. If masses are within .05 g, clean up your station. If not, repeat step five until the two subsequent mass readings are within .05 g of each other or time is called.
6. Obtain the results of the other lab groups and record.

Data Table

Your table will resemble this one. You need to make one that fits all your data needs. If you need more heatings, record those masses too.

Mass of evaporating dish, watch glass and hydrate	
Mass of empty evaporating dish and watch glass	
Mass of hydrate before heating	
Mass of copper sulfate after first heating	
Mass of copper sulfate after second heating	
Mass of water evaporated	
Ratio, by mass, of copper sulfate to water	
Ratio, by mass, of copper sulfate to hydrate	
Ratio, by mass, of water to hydrate	
Ratio, by moles, of copper sulfate to water	
Ratio, by moles, of copper sulfate to hydrate	
Ratio, by moles, of water to hydrate	

Calculations

Show a complete set of calculations in order to complete the table above. Then show how you determined the formula for the copper sulfate hydrate.

Analysis

Write a complete analysis. Answer the attached questions.

Paragraph 1: Purpose

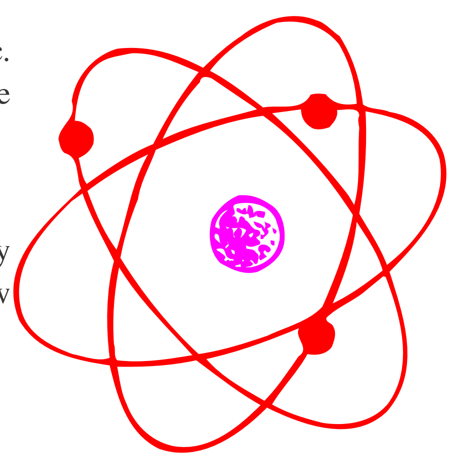
What major concept in atomic theory was demonstrated in this lab? *Hint:* what are the atomic laws? Does this lab support the law of multiple proportions, definite proportions or the law of conservation of mass? What was your hypothesis? Was it supported or refuted?

Paragraph 2: Data Interpretation

What is your evidence to support the law this lab supports? Be specific. What is the experimentally determined formula of this copper sulfate hydrate?

Paragraph 3: Error Analysis

Give two major sources of error in the data collection and how they affected the results? Explain your chain of reasoning for these results. How could you reduce these major sources of error?



Atomic Theory Lab Discussion Questions

1. Why do we mass the evaporating dish and watch glass and then add the hydrate rather than zeroing the balance with the glassware on the balance pan?

2. Does the change in color represent a physical or chemical change? Why?

3. Write the correct formula for your hydrate. Do the coefficients represent ratios of moles of hydrate to compound or the ratios of masses of hydrate to compound?

4. What is the significance of heating the substance until two sets of masses are very close to each other?

5. How would your ratio of moles of water to moles of compound change if you did not actually evaporate all the water from the hydrate? Explain your chain of reasoning.

6. What is the percent by mass of water in the formula for this hydrate? What is the percent by mass of oxygen? Show all work.

Atomic Theory Lab Discussion Questions Answers

1. Why do we mass the evaporating dish and watch glass and then add the hydrate rather than zeroing the balance with the glassware on the balance pan?

   Because we can't measure the mass of solid post-heating the same way

2. Does the change in color represent a physical or chemical change? Why?

   Physical...no change in chemical composition merely anhydrous form

3. Write the correct formula for your hydrate. Do the coefficients represent ratios of moles of water to compound or the ratios of masses of water to compound?

   $CuSO_4(5H_2O)$ ~ ratio of 5:1 is moles of water to moles of copper(II) sulfate

4. What is the significance of heating the substance until two sets of masses are very close to each other?

   To be sure all water was evaporated

5. How would your ratio of moles of water to moles of compound change if you did not actually evaporate all the water from the hydrate? Explain your chain of reasoning.

   The mass of the compound without the water would be higher than expected. Therefore the number of moles would be higher. The mass of the water would be less, so the number of moles would be less. This results in a formula with too high a coefficient for the compound, too low for the water

6. What is the percent by mass of water in the formula for this hydrate? What is the percent by mass of oxygen? Show all work.

   Mass water x 100 = % **For CuSO4(5H2O) 36% water, 58% oxygen**
   Mass of hydrate

"… what AVID shows is that high minority achievement can be more ordinary when schools not only insist on academic rigor but also offer personal support. AVID offers a blueprint for this scaffolding."

—Richard Rothstein, *New York Times*

Activity 7.9 (1 of 9) **_Teacher Guidelines_ (1 of 4)**

Caffeine Lab

AP Discipline

Environmental Science or Biology

Timeline

90 minutes

WIC-R Strategies

- Writing
- Inquiry
- Collaboration

Concept Statement

This lab uses caffinated soda to demonstrate the effect of caffeine on physiological responses while teaching students experimental design and variable control through a purposely "flawed" lab. The intent behind this lab is to help students understand the importance of being able to identify and control extraneous experimental variables, and to clearly show that the quality of the data collected, and conclusions inferred, are directly related. Students will "discover" the sources of error in this lab as they learn about hypothesis development, double-blind and placebo studies.

Lesson Plan

Recommend as a first lab of the semester. No prior knowledge is needed.

1. Gather the needed materials. Obtain diet caffeinated soda and diet decaffeinated soda. *Note:* Students tend to prefer the taste of regular caffeinated soda, but then you are adding the additional variable of sugar—an uncontrolled variable in this lab. You'll need about one liter of each per class, as well as a supply of drinking water for the control group. Wrap each bottle in construction paper to hide its "identity" before pouring cups for the class. Determine the soda with caffeine at random (A or B). You'll also need to get 5 oz. paper cups, one for every student.

Diet Caffeinated

Diet Decaffeinated

Water

2. Photocopy both the ExD templates (Unit 6) and a copy of the Caffeine Lab for all students. (See sample ExD for this lab below).

Sample

Complete this ExD planning form BEFORE beginning a lab

Lab Title

The effect of _Caffeine______ on ___Pulse Rate___.

Hypothesis

Use an if/when... then... statement. State the cause & effect relationship between the DV and the IV. The hypothesis must be testable.

If caffeine [increases/decreases] heart rate then the pulse will go [up/down]. (varies)

Experimental Condition	**Soda A**	**Soda B**	**Water (Control)**
# of Trials	# of A drinkers	# of B drinkers	# of C drinkers

Independent Variable

What is the cause agent? What are you changing? **TYPE OF SODA (Caffeinated or decaffeinated)**

The number of columns will vary depending on how many testing conditions exist in the experiment.

Dependent Variable

What is being measured? **PULSE RATE**

Control

What is the experimental group being compared to?

The pulse rate of the water drinkers (no soda).

Experimental Constants

Variables not altered during the experiment

- **Quantity drink consumed**
- **Conditions of testing (environment)**
- **Way pulse is measured**
- **Time**

Sketch of Experimental Set-Up

Label clearly and attach.
Students can do this part.

Pre Lab

Students may have some idea about the scientific method, and you may want to find out how much they already know. Few students understand the way the Dependent Variable DV and the Independent Variable IV are central to practicing good experimental design, or to the way these variables are connected to graphing.

- Have the students read the lab.
- Review the ExD template as a class.
- Instruct students how to take a wrist pulse. Students may want to take their own (and not be touched by the Researcher). This is one of the many uncontrolled variables in this lab. This is your call. If you are doing this the next day, you can ask students not to eat chocolate or drink caffeinated drinks before the lab (students usually 'forget' however, another uncontrolled variable). Sugar intake is another uncontrolled variable.
- Ask the students about the variables that we many need to control in this experiment. Make a list of those they mention (you'll return to it after the lab). Don't give them suggestions at this point.
- DON'T tell students which soda actually had the caffeine, they are to use their data to infer it (although given the lab set-up and the small quantity of soda consumed this is nearly impossible.)

During Lab

Dispense the solutions to the research teams. Each lab group should drink in unison to keep the timing consistent. (There will inevitably be problems however). The Researcher is keeping the data for the other members of the team. Each student will need to make their own data tables for the class data. However, find a place for students to record the class data—see below.

Sample: Class Data Table

	Person A (Rate)	**Person B (Rate)**	**Person C (Rate)**
Lab Team 1	+6 (M)	-2 (F)	-10 (F)
Lab Team 2, etc.	-1 (F)	+4 (M)	+3 (M)
Average Rate			

- Students may need help with the graphing instructions. You may need to sketch a sample graph on the board.
- Students may not understand what is meant by "disaggregation" of the data (seperation of the data by criteria such as gender, athlete, age).
- Students may need help understanding that the soda with the largest increase in pulse rate, probably was the caffeinated one. If the water has the largest increase, then they'll have an opportunity to explain why this may have happened.

Post Lab

Lead a discussion about what the data showed and why this may be a "flawed" experiment. Typically the data collected is random and shows no clear trend for identifying the caffeinated soda. The point here is that scientists frequently work in the dark, with only their experimental data to guide their conclusions. Bad data = bad conclusions. This lab simulates a similar situation. Revisit the list of variables - which ones did we fail to control? They should be able to generate a list of 10 to 12. Have students complete the lab questions and bring to class. This may be their first written Lab Report with analysis. Have teams of students "peer review" the analysis paragraphs and give feedback to their peers. If the paragraphs are inadequate, have the students revise up to the standard.

Extension Activity

Students frequently get interested in the caffeine consumption issue. The following pages have a list of common beverages and foods with their caffeine contents. Assign students to list their consumption from Student Handout "Caffeine Content of Food and Drugs" and calculate how much caffeine they consume per day. They can then take the survey to 10 of their friends and family and compile the data for further class analysis.

Safety Admonition

Do not share cups with other students or mix the contents of one cup with another. Do not use great pressure when taking your own pulse or that of another. Follow all lab directions carefully.

Caffeine Content of Foods and Drugs

Sources: National Coffee Association, National Soft Drink Association, Tea Council of the USA, and information provided by food, beverage, and pharmaceutical companies and J.J. Barone, H.R. Roberts (1996) "Caffeine Consumption." *Food Chemistry and Toxicology,* vol. 34, pp. 119–129.

Product	Serving Size	Caffeine (mg)
Over The Counter (OTC) Drugs		
NoDoz, maximum strength	1 tablet	200
Excedrin	2 tablets	130
NoDoz, regular strength	1 tablet	100
Anacin	2 tablets	64
Coffees		
Coffee, brewed	8 ounces	135
Coffee, decaffeinated	8 ounces	5
Coffee, instant	8 ounces	95
GF International Coffee, Cafe Vienna	8 ounces	90
GF International Coffee, Swiss Mocha	8 ounces	55
GF International Coffee, Viennese Chocolate Café	8 ounces	26
G. F. International Coffee, Orange Cappuccino	8 ounces	102
Maxwell House Cappuccino, Mocha	8 ounces	60–65
Maxwell House Cappuccino, French Vanilla or Irish Cream	8 ounces	45–50
Maxwell House Cappuccino, Amaretto	8 ounces	25–30
Maxwell House Cappuccino, decaffeinated	8 ounces	3–6
Teas		
Celestial Seasonings Iced Lemon Ginseng Tea	16-ounce bottle	100
Bigelow Raspberry Royale Tea	8 ounces	83
Tea, leaf or bag	8 ounces	50
Snapple Iced Tea, all varieties	16-ounce bottle	42
Lipton Natural Brew Iced Tea Mix, unsweetened	8 ounces	25–45
Lipton Tea	8 ounces	35–40
Lipton Iced Tea, assorted varieties	16-ounce bottle	18–40
Lipton Natural Brew Iced Tea Mix, sweetened	8 ounces	15–35
Nestea Pure Sweetened Iced Tea	16-ounce bottle	34
Tea, green	8 ounces	30
Arizona Iced Tea, assorted varieties	16-ounce bottle	15–30
Lipton Soothing Moments Blackberry Tea	8 ounces	25
Nestea Pure Lemon Sweetened Iced Tea	16-ounce bottle	22
Tea, instant	8 ounces	15
Lipton Natural Brew Iced Tea Mix, diet	8 ounces	10–15
Lipton Natural Brew Iced Tea Mix, decaffeinated	8 ounces	<5
Celestial Seasonings Herbal Tea, all varieties	8 ounces	0
Celestial Seasonings Herbal Iced Tea, bottled	16-ounce bottle	0
Lipton Soothing Moments Peppermint Tea	8 ounces	0
Soft Drinks	***Serving***	***Caffeine (mg)***
Josta	12 ounces	58
Mountain Dew	12 ounces	55.5
Surge	12 ounces	52.5

Product	**Serving Size**	**Caffeine (mg)**
Soft Drinks	***Serving***	***Caffeine (mg)***
Diet Coke	12 ounces	46.5
Coca-Cola classic	12 ounces	34.5
Dr. Pepper, regular or diet	12 ounces	42
Sunkist Orange Soda	12 ounces	42
Pepsi-Cola	12 ounces	37.5
Barqs Root Beer	12 ounces	22.5
7-UP or Diet 7-UP	12 ounces	0
Barqs Diet Root Beer	12 ounces	0
Caffeine-free Coca-Cola or Diet Coke	12 ounces	0
Caffeine-free Pepsi or Diet Pepsi	12 ounces	0
Minute Maid Orange Soda	12 ounces	0
Mug Root Beer	12 ounces	0
Sprite or Diet Sprite	12 ounces	0
Caffeinated Waters		
Java Water (1/2 liter)	16.9 ounces	125
Krank 20 (1/2 liter)	16.9 ounces	100
Aqua Blast (1/2 liter)	16.9 ounces	90
Water Joe (1/2 liter)	16.9 ounces	60–70
Aqua Java (1/2 liter)	16.9 ounces	50–60
Juiced	10 ounces	60
Chocolates or Candies		
Hershey's Special Dark Chocolate Bar (1 bar)	1.5 ounces	31
Hershey Bar (milk chocolate) (1 bar)	1.5 ounces	10
Cocoa or Hot Chocolate	8 ounces	5
Frozen Desserts		
Ben & Jerry's No Fat Coffee Fudge Frozen Yogurt	1 cup	85
Starbucks Coffee Ice Cream, assorted flavors	1 cup	40–60
Häagen-Dazs Coffee Ice Cream	1 cup	58
Häagen-Dazs Coffee Frozen Yogurt, fat-free	1 cup	40
Häagen-Dazs Coffee Fudge Ice Cream, low-fat	1 cup	30
Starbucks Frappuccino Bar 1 bar	2.5 ounces	15
Yogurts, one container		
Dannon Coffee Yogurt	8 ounces	45
Yoplait Cafe Au Lait Yogurt	6 ounces	5
Dannon Light Cappuccino Yogurt	8 ounces	<1

The Caffeine Experiment

Background

"Caffeine is one of the world's most widely used drugs and is present in 63 different plant species. Caffeine is a flavoring agent and stimulant in some foods and drinks. It also serves as a filler with prescription and over-the-counter drugs. Some pain relievers, diuretics, cold remedies, and weight control products may contain caffeine. The amount of caffeine in soft drinks varies from brand to brand. For instance, 12 ounces of Jolt® contains 71 mg; whereas the same amount of Pepsi-Cola® has 37 mg and 12 ounces of Mountain Dew® has 55 mg of caffeine. Because of increased portion sizes and accessibility of beverages containing caffeine, Americans of all ages are consuming more caffeine."

By Felisha L. Rhodes, Donna McDuffie, "Nutrinet," Aug 2000. Available from http://www.extension.umn.edu/infou/nutrition/BJ884.html

Question

Will the caffeine in caffeinated soda or decaffeinated soda cause a person's pulse rate to go up? What's your initial hypothesis? *(pick one)*

The caffeine **will** increase heart rate _____ The caffeine **won't** increase heart rate ____

Experimental Design

Using the ExD format, complete the template for this lab.

Materials and Methods

1. Each lab group of four will provide three experimental subjects: One is "Person A" who drinks soda "A" and the other is "Person B" who drinks soda "B" and the third is "Person C" (the control, who drinks water).

Person A ______________________________ Person B ______________________________

Person C______________________________ Researcher: ______________________________

2. Each experimental subject will get their pulse taken by the group Researcher and this data will be recorded in the data table on all the lab team papers.
   - Record A and B and C's pulse rates for 60 seconds under "Starting pulse rate" below.
3. The Researcher will go fetch the testing solutions and administer to the following at the same time:
   - Person A who will now drink 84 grams (3 ounces) of soda "A"
   - Person B who will now drink 84 grams (3 ounces) of soda "B"
   - Person C who will now drink 84 grams (3 ounces) of water.
   - *One of the solutions is "decaffeinated soda" (the placebo) and the other is caffeinated soda (the experimental substance). No one knows which is which except the Chief Researcher, who also happens to be your teacher.*

4. Wait eight minutes after drinking Solution A, B and C. The Researcher times A, B and C while the solutions take effect.
5. The Researcher takes person A, B and C's pulse for 60 seconds a second time. Record the information below under "Final Pulse Rate."

Results

Lab Team Data Table

Person	Starting pulse rate in Beats/min.	Final pulse rate in Beats/min.	Rate increase (+) or Rate decrease (-)	Male or Female
Soda A				
Soda B				
Water C				

Rate = final pulse rate - starting pulse rate. If (+), then rate increased, if (-) then the rate decreased. Record the gender of the test subjects here too.

6. The Researcher now goes to the board and records the Lab Team data on the Class Results chart on the board. All members of the lab group copy down the Class Data.

Sample: Class Data Table

	Person A *(Pulse Rate & gender)*	Person B *(Pulse Rate & gender)*	Person C *(Pulse Rate & gender)*
Lab Team 1			
Lab Team 2			
Average Rate			

Total class sample size = ____________ Males = ______ Females = _______

Analysis of Results

- Determine the average pulse rate of all the A's, B's and C's and record it in your Class Data Table.
- Then, disaggregate the data by putting the males (A, B, C) in one data table and the females (A, B, C) in another and finding the average pulse rate by gender.
- Make a BAR graph of the whole class results on a piece of graph paper - this will have 3 bars.
- Hints for graphers: The dependent variable (change in pulse rate) goes on the Y axis and the independent variable (A, B, C) goes on the X axis. One bar is for average pulse rate of Group A, the second for average pulse rate of Group B and the third for Group C, the control (water).
- Make a second graph on another piece of graph paper of the disaggregated gender data—this will have 6 bars, 2 for A (M and F), 2 for B and 2 for C.

- All graphs must have a title, clearly labeled X & Y axes, and a brief one sentence conclusion written below the graph.

Analysis

Using a paragraph format, include the following in your lab analysis.

***Paragraph 1:* Purpose**

What concepts in experimental design were demonstrated in this lab? Hint: Did this investigation answer the research question adequately? Why or why not? Did this experiment have a placebo? What was it?

***Paragraph 2:* Data Interpretation**

According to your experimental results did caffeine increase, decrease or have no effect on heart rate? What evidence do you have to support your conclusions (use data from the lab)? Which group (according to class results) was the caffeine group? Which group (according to class results) was the decaffeinated group? What did the control group show? What evidence do you have from the graphs to support your conclusion? Did you support or fail to support your original hypothesis? Explain.

***Paragraph 3:* Error Analysis**

Give two major sources of error in the data collection and how they affected the results. Explain your chain of reasoning for these results. How could you reduce these major sources of error? What variables were not controlled (sources of error)? For example, does it matter if the test subject is male or female?

***Paragraph 4:* Extension**

How could you design a caffeine experiment to control these errors? Note the kind of equipment you might need to increase the accuracy. (Be specific and list the steps.)

Extension

List your caffeine use and calculate how much caffeine you consume per day. Take the list to 10 of your friends and family and compile the data for further analysis.

Bioassay of Ammonia on Bloodworms: Finding the L.C.- 50

AP Discipline

Environmental Science or Biology

Timeline

1 preparation period and 1 lab period; 50 minutes each.

WIC-R Strategies

- Writing
- Inquiry
- Collaboration
- Reading

Concept Statement

This lab explores the topic of toxicity by introducing students, working in collaborative lab teams, to the way in which lethal concentrations (LC) of substances in aquatic environments are measured by environmental scientists. Students may already be familiar with the term LD (lethal dosage). During this investigation students are presented with a problem to be solved—finding experimentally what the LC-50 for ammonia is for a common species of aquatic worms. Students should be familiar with aquatic ecosystems, pollution, run-off and experimental design.

Lesson Plan

- Bloodworms can be obtained from a local fish store for a very economical price. They are very hardy and can survive most classroom conditions for several days.
- If bloodworms are not available, you can substitute brine shrimp and run the same lab. However, you would want to give students some additional background information on brine shrimp.
- Obtain normal 'household' ammonia and put it in dropper bottles—one per each student team.

Pre Lab

- Students will work in teams, and teams must be able to collaborate and divide up work efficiently. Have the lab teams design their ExD the day before the lab and have a plan to complete all the parts.
- Check the ExD's before students begin work to make sure they have identified the DV (# of worm deaths) and the IV (ammonia concentration).

- Set out the needed materials before class begins. Show the students what equipment is available and have them read through the lab before they begin.
- You many want students to do some additional research as a lab team, if so provide them with some readings, or have them search the web for more background information on lethal concentrations, bloodworms and aquatic environments.
- Each lab team will hand in one report—so this is an important part of the lab work. One person working will not be able to complete it alone.
- Inform students that you will not answer questions, it will be up to them to problem solve and get the work done.
- Have one person from each lab team collect the materials and begin work.

During Lab

- Distribute the worms and materials to the student teams at their request. Do not remind students what they need. Part of this exercise is to design a procedure and then carry it out in the allotted time.
- Circulate and observe, but again, offer no suggestions. Your students may get grouchy about this "lack of help" however, it's their turn to show what they know.

Post Lab

- Have the students follow the lab directions for compiling their work and getting it turned in. The following day, lead a discussion about what they found, what problems they encountered and how they worked as a team. This can also be a written piece in the Interactive Notebook. You may want to put up the individual group results (LC-50 for ammonia) as class data. How does looking at more data sets influence their conclusions?

Safety Admonition

Students need to wear appropriate lab attire including goggles and aprons. Before allowing students to work with any chemicals, refer to the MSDS sheet for associated risks and safety concerns. Instruction as to safe use must accompany any new equipment and chemicals.

Bioassay of Ammonia on Bloodworms: Finding the L.C.-50

Question

What is the lethal concentration (LC) of Ammonia that will kill 50% of bloodworms, a common aquatic organism.

Essential Background Information

In dealing with toxins in the environment, scientists refer to the relative danger or potency of a particular poison by using a unit of toxicity called the LD-50. This means "the lethal dosage of a substance that is lethal to 50% of the population of organisms in the sample." For example, if you had a population of 100 rats and fed each one an equal dose of 30 grams of sugar and 50 of the rats died of the original 100, then, we would say that the LD-50 of sugar in rats is 30 grams.

Now if the same experiment were performed with nicotine, a mere 0.05 grams of nicotine would have the same effect, killing 50% of the rat population. Therefore, it could be determined that the LD-50 of nicotine in rats is 0.05 grams. By the way, nicotine is more toxic to humans than strychnine (rat poison). Therefore, nicotine has a high mortality (death) rate.

The LC-50 is similar to the LD-50, but it refers to the concentration of a substance that the organism is exposed to. This is especially useful to scientists, because varying concentrations of toxins get into our environment that may be harmful or deadly to the local organisms. It all depends on how concentrated the substance is and how sensitive the species is to the toxin. For example, dioxin, a toxic by-product of the processes used in the manufacture of herbicides and in bleaching of paper, has a lethal effect on some marine fish. Mackerel are more susceptible that blue sharks, therefore the lethal concentration would be lower for mackerel than blue sharks. Often species are used as markers, or an indicator species, to determine if a lethal concentration is present for other organisms. If they begin to die in large numbers it indicate a DANGER signal that something is wrong with the environment.

Bloodworms are a common organism used for feeding aquarium fish. The bloodworm *(Glycera dibranchiata)* belongs to a phylum of animals known as the Annelids. This group of organisms usually has an elongated, cylindrical shaped body consisting of a series of similar segments. Bloodworms inhabit the intertidal and subtidal regions of mud flats. They can survive in areas with low oxygen levels and have the ability to tolerate fluctuating salinity rates. Bloodworms are found along the Atlantic seaboard from the Gulf of St. Lawrence to Florida, as well as along the Gulf of Mexico to Texas. They also live on the West coast from California to Mexico.

Lab Team Requirements

You are to produce a quality scientific lab report as the result of this experience. The report shall include the following:

1. Explanation of the scientific concept behind this experiment.

2. An experimental design, including a hypothesis (make a prediction regarding the LC-50 rather than a statement of fact).
3. A step-by-step procedure of how the experiment was conducted. Including an explanation of the control procedure (the test group used for comparison) and the test groups.
4. A complete data table that shows the effects of different concentrations of ammonia on bloodworms (quantitatively) and all recorded observations collected during the experiment.
5. A clearly labeled line graph of the data (Plot a line graph of Ammonia Concentration versus bloodworm mortality [death]). *From the graphed data determine the LC-50 and the LC-100 of the Ammonia on the Black worm population under study. Mark these specific values on your graph.*
6. Analyze the data, and explain specific conclusions reached regarding the LC-50 of ammonia on bloodworms. *Allow the analysis questions to guide your explanation.*

Methods

- Part of the challenge in this exercise is to develop a good experimental design; therefore the procedural instructions will be kept to a minimum. It is your job to develop the specific methods used.
- You are to observe bloodworms in seven different concentrations of ammonia water.
- Complete the following table (and incorporate it into your data table). It gives the concentration of ammonia, in ppm (parts per million). If you add a specific number of drops of "household" strength ammonia to exactly 10 ml of tank (aquarium) water then, 1 drop of ammonia = 250 ppm of ammonia (see chart below).

Take care not to change the concentration of ammonia when adding the worms

Ammonia (NH_3) Concentration in ppm

NH_3 Concentration	Drops of Ammonia per 25 ml H_2O	Bloodworm Mortality
250 ppm	1 drop	
500 ppm		
750		
1000	4 drops	
1500		
2000		
2500		

Other Materials Available:

- Petri dishes
- Dropper bottles of Ammonia
- Modified pipettes for collecting the worms
- *Hint:* Use 10 bloodworms for each concentration (it makes the math easier).

Helpful Hints for Experimenters

- What will be the control in this experiment?

- Observe each sample for the same length of time; three minutes should be ample for the ammonia to have an effect. How many worms do not survive the three minutes in the specific concentration?
- After you have finished, dump the worms in the specified containers. After cleaning, they will be used to feed the lucky aquarium fish.

Analysis

From your data table, **graph** the data using a line of best fit and identify the LC-50 and LC-100, marking these concentrations with a line and/or a label.

Use the following questions to guide your analysis write up. Be sure to identify any possible sources of error and propose a new experimental procedures or investigations. Write the analysis in paragraph format, following the lab report rubric.

1. What concentration (ppm) of ammonia would kill exactly 50% of the bloodworm population? What concentration would kill 100%?
2. What would you consider to be the safe-threshold concentration of ammonia for bloodworms? Explain, and indicate the data that support your explanation.
3. Ten ppm is the acceptable concentration of ammonia in drinking water in the United States. What conclusions can you make in comparing humans and bloodworms to their tolerance of ammonia?
4. Biologists use certain organisms as indicator species. These are specific species, which are watched closely to determine the health of a certain ecosystem and to determine how safe the ecosystem is for all its inhabitants. Would bloodworms be a good indicator species? Explain why or why not. Again refer to the data you collected.
5. Design another experiment using another substance and recommend which species might be used as the indicator species for determining the LC-50. How could you improve the experimental design in your experiment?

Packums: Determining Population Size

AP Discipline

Environmental Science or Biology

Timeline

50 minutes

WIC-R Strategies

- Writing
- Inquiry
- Collaboration
- Reading

Concept Statement

This lab simulates the mark, capture, release procedures performed by environmental biologist to determine (estimate) the population sizes of species in the wild. Students use "packums," the styrofoam pieces that accompany many packages and mark, capture and release them into the "environment." Students use a series of calculations to predict the actual number of packums, and then verify their calculations by actually counting the whole population. This exercise allows them to see how our estimations of wild populations are just that—estimations.

Lesson Plan

This activity can be used with the unit on population, or along with population genetics.

Collect as many packums from the shipping boxes flowing into your science department. You'll need enough packums for each student team of three to have approximately 400–500. However, packums can be reused year after year. Each lab team will need a large grocery store size paper bag (the enviro-bag). Students should not be able to see into the bag in order to make the capture and recapture process more random.

Pre Lab

1. Photocopy the lab sheets for students.
2. Have a supply of colored markers for students to "mark" their packums.
3. Have students read through the lab, either for homework or the day before.

During Lab

Monitor students marking and pulling the packums. Make sure they return the marked ones to the bag and follow the lab instructions. Have them construct their own data tables and do the calculations on their own papers.

Post Lab

Discuss the class results. You may want to collect class data to show the spread of results. This reinforces the "uncertainty" of science in which predictions are always subject to change when more information becomes available.

Safety Admonition

Do not place the packum material in your mouth. Follow all lab directions carefully.

Packums: Determining Population Size

Question

How do environmental biologists determine population size in the wild?

Background Information

Population surveys are often used to determine our societie's status, health and genetic variability. Scientist collect data to determine if a species is endangered, threatened or too populous for an area and to answer the following questions. Should hunting permits for the species be issued? Is a disease threatening the population? How common are different genetic traits in a population? Which species should be protected by law from hunting or by environmental controls?

Task

- Each team will attempt to determine the total population of an animal (the packum) in a controlled environmental area.
- The total population will be approximated using a mark, release, recapture method commonly used by wildlife biologists.

Methods

Before beginning the testing, make a data table to record your results.

Mark and Release:

1. Get a enviro-bag of PACKUM animals.
2. Shake the enviro-bag to "randomize" the distribution of the PACKUMS.
3. Reach into the enviro-bag and pick out 10 to 20 PACKUMS.
4. Place an easily recognizable mark on the back of each PACKUM.
5. RELEASE each of the MARKED PACKUMS back into the enviro-bag.
6. Shake to "randomize" the distribution of the PACKUMS.
7. Without looking, have one of the team reach into the enviro-bag and remove one PACKUM.
8. Record if the PACKUM is marked or unmarked on your data table.
9. If this PACKUM is not marked, DO NOT mark it.
10. Release the PACKUM back into the enviro-bag and shake once more.
11. Continue to CAPTURE, record, then RELEASE the PACKUMS until a total of **100** have been captured.
12. When totally done, empty out the entire enviro-bag of PACKUMS and count the actual number of PACKUMS present in the enviro-bag.
13. Be sure to keep the marked PACKUMS out of the enviro-bag. Place the marked PACKUMS in a different designated place in the room.

Data Collection Results

Fill in the appropriate numbers in the charts below as you are completing the steps above.

Data Table

Use tally marks as you capture, and release and recapture 100 (or more) Packums.

Number of Unmarked PACKUMS	Number of Marked PACKUMS

Description	Symbol	= Number
Estimated number of packums in the container *(Your best guess)*	= E	
Original number of marked packums *(Number you put a mark on)*	= M	
Total Packums captured from the Enviro-bag *(Use the data above and sum the Unmarked + the Marked)*	= C	
Number of recaptured packums *(These were PACKUMS captured that were marked from table above)*	= R	
Total number of Packums counted after all testing done *(All the Packums in the Enviro-bag get counted now)*	= T	

Analyze Data

A. Calculate the **total number** of PACKUMS in the enviro-bag using the formula below:

$N = \frac{C \times M}{R} =$ ______________________

Number of Packums from calculation A (see formula above): N = ___________________

*N is the **calculated** number of PACKUMS in the container.*

B. Determine the **percent error** in the data using the formulas below: (a negative % error indicates your estimated number was below the true value, a positive % error, that it was above the true value).

1. Percent error between the estimated number of packums (E) and the actual number of packums (T):

% error = $\frac{100 \times (E - T)}{T}$ **= % error =** ______________

2. Percent error between the calculated number of Packums (N) and the actual number of Packums (T)

$\% \text{ error} = \frac{100 \times (N - T)}{T} =$ % error = ______________

C. Calculate the percent error between the Estimated number (E) and the calculated number (N) of PACKUMS:

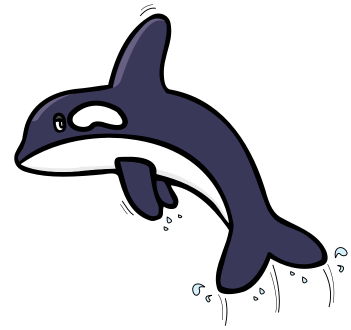
$\% \text{ error} = \frac{100 \times (E - N)}{N} =$ % error = ______________

Analysis

Include the following information in several well written paragraphs.

- Remember to explain how the discrepancy in the real population numbers (T) compares to the calculated population numbers (N) and your estimations (E).
- Where were the percent errors the greatest? Explain.
- In what cases would a smaller N benefit the species? A larger N?
- Why do you think this method is used in the wild if it does not reflect the actual population sizes?
- What techniques might be used to better estimate the total population of PACKUMS or any other animal in an area?
- When you hear about the numbers of a wild species reported on the news, what will this activity cause you to reflect on?

Why Don't Whales Have Legs?



L. Hays adaptation of work by S.J. Bedell, ENSI at CSUSU, 1992

AP Discipline

Environmental Science or Biology

Timeline

30 minute pre-lab and 50 minute lab period

WIC-R Strategies

- Writing
- Inquiry
- Collaboration

Concept Statement

In this lab students design an experiment to test their hypotheses about why whales don't have legs. It uses simple materials to address the issue of how natural selection accounts for the reduction of whale legs due to heat loss. Selection favors a body design that is energy efficient. The task of the students is to design an experiment to discover this. It ties in with evolutionary theory and propels classroom discussion about environmental pressure resulting in genetic selection. This lab can also be used as an assessment—students work in collaborative teams to problem solve, design and carry out an experiment.

Lesson Plan

This activity can be used with the unit on natural selection or evolution and will reinforce the concepts introduced in population genetics.

This is a very open ended lab that is student centered. There is a minimal necessity for background information from the teacher. Whales are warm-blooded marine mammals who must maintain body temperature within a narrow range. Their adaptations to the cold marine environment include reduction of limb size and addition of blubber as an insulator.

This lab is designed to demonstrate to the students the above adaptations. The latex (or plastic) glove simulates a marine mammal with limbs. The plastic baggies simulate a marine mammal without limbs. The styrofoam cup simulates blubber.

Safety Admonition

Use caution when handling hot water. Make sure thermometers are not allowed to roll off the lab surface. Do NOT shake the thermometers. Follow all lab directions carefully.

Pre Lab

Materials needed (per group;): container that holds water, 1 latex glove, 2 small zip-lock type plastic baggies, 1 400 ml. graduate beaker, 1 styrofoam cup (large enough to hold full plastic baggie), heat source (or source of very hot water), ice cold water, thermometer.

The intent of the lab is for the students to fill the latex glove and baggies with warm water, float them in cold water and measure the rate of heat loss. The students can also put one baggie in the styrofoam cup to insulate it against heat loss. (Students will come up with other ways to use the materials, which should be encouraged.) If they get stuck, you may ask them—what can you measure? That's the dependent variable (water temperature). The students, however, should NOT be told the purpose of the materials as this is an inquiry lab. Hints can be given at teacher discretion.

Day 1: **Pre Lab**

Lead a discussion (or watch a video) about whales and marine mammals. Ask, if whales are mammals, why don't they have legs? After all, sea lions and otters do.

1. Have student teams of three or four use the ExD chart to design their lab and draft a data table. Ask them to develop sketches of what they plan to do tomorrow and fill out a methods section. Remind them that these plans often get modified in the real world of science, but you've got to begin with a plan.
2. Distribute the materials and ask students to design an experiment that will result in a reasonable explanation of, "Why whales don't have legs?"
3. Instruct students to keep in mind the elements of a good experiment. *Optional teacher hints:* What's the difference between a fish and a whale? A good experiment should have only one variable. Why do you have a thermometer?
4. Circulate and give hints as needed. Approve viable experiments.

Day 2: **During Lab**

Instruct the students to use their plan and materials to do their experiment. After they have collected the data, have them submit a group lab report consisting of their ExD, materials, methods, experimental set-up, data, and analysis. The analysis should answer the question of why whales don't have legs, and support it with data from the experimentation (see below).

1. Analysis of experiment.
   a. Did your conclusion support your hypothesis?
   b. Give your instructor a one sentence rationale of, "Why whales don't have legs?"
   c. What was the purpose of the styrofoam cup?
   d. To what modern adaptation does the styrofoam cup correspond?
   e. What is adaptive advantage of a sea lions legs?
2. Presentation of data by a selected student group to the rest of class or two lab group meet and report out to each other.
3. Going further questions.
   a. Analyze other marine animals and their adaptations to the marine environment.
   b. How would natural selection operate to support the evolution of the fully aquatic mammals such as whales from terrestrial mammals?

Why Don't Whales Have Legs?

The Question

Why don't whales have legs?

The Task

1. Design an experiment using the ExD format using these materials that will result in a reasonable explanation of "Why whales don't have legs?"
2. Look over your list of materials before you begin and consider carefully how you could use each of these to demonstrate the properties of whales.
3. Keep in mind the elements of a good experiment. (*Note:* A good experiment should have only one variable). Include detailed sketches in your design and the methods you will follow and design a data table.
4. You must finish your experimental design during class and have it approved by your instructor.

Materials *(per group of 3 or 4 students)*

- Plastic shoe box
- 1 rubber glove
- 1 styrofoam cup
- Ice water
- 2 small zip-loc type plastic bags
- 1 thermometer
- Very hot water
- 1 graduated beaker (400 ml.)

Your Task, Tomorrow

1. Using your ExD and the materials provided, perform your experiment. Include the following in your analysis section and use complete sentences.
   - Did your conclusion support your hypothesis?
   - Can you give your instructor a one-sentence rationale of "Why whales don't have legs?"
   - About the cup:
     — What was the purpose of the styrofoam cup?
     — To what modern adaptation does it correspond?
     — Why was this idea included in this lab?
2. How would natural selection operate to support the evolution of the fully aquatic mammals such as whales from terrestrial mammals?
3. Turn in a group lab report with your title page, ExD, sketches, materials and methods, data table, graph, and analysis.

“We have learned how thin the evidence base is, that is to say, how many decisions are being made on the basis of anecdote or impressions or sales pitch or, in a more positive way, professional judgment of good people … the programs that can show, not just say, but show that they can produce—those are the programs that should be funded. And AVID is one of those programs.”

—John Yochelson
Executive Director, BEST (Building Engineering and Science Talent)

Activity 7.13 (1 of 7) ***Teacher Guidelines* (1 of 4)**

Hooke's Law Lab

Lab designed by Martin Teachworth, Physics Teacher, La Jolla HS, San Diego, CA.

AP Discipline

Physics

Timeline

45–90 minutes

WIC-R Strategies

- Writing
- Inquiry
- Collaboration
- Reading

Concept Statement

This lab provides a way for students to directly experiment with an important concept in physics and to reinforce the use of graphing to "see" mathematics. The types of graphs (see following section) should be given to students for their InterActive Notebooks to refer to during the year. The lab testing will be done in a relatively short period of time. However, the lab analysis and discussion of related topics will take place over several days. The idea is NOT to teach about Hooke's Law, but is to have students learn or review many concepts and skills. Some students will not understand the need to learn ideas and skills. Frustration at not having definite facts to memorize may disturb some students. It is essential students be told WHY the lab is being done. Stress the learning of how to think and act like a scientist, not the memorization of information that may not be understood.

Lesson Plan

The lab is written and explained as if it were the first lab of the year in a physics or physical science class.

Teacher Prep

(See the set-up diagram on the student lab page).

The equipment needed to do the lab testing is relatively simple. Rubber bands may be obtained from nearly any source. Ring stands are nice, but not necessary. The rubber band could be connected to the table top and stretched vertically along a leg or connected to the edge of the table and be pulled along the table top. Spring scales could be in grams or Newtons. Use a spring scale with a range of at least 0 to 2000 grams or 0 to 20 Newtons. A spring scale with a smaller range is too sensitive and a spring scale with a greater range is not sensitive enough. A standard 30.0 cm ruler divided into millimeter increments is also needed. The ruler could be held in place by taping it to the ring stand or desk. Expensive stands with special rulers and points may be purchased from various vendors, but the idea is to show students scientific relationships exist everywhere in the world and may be shown using simple materials.

If a variety of rubber bands are used, the slopes of the graphs between groups will vary. If different rubber bands are used, then the different slopes of the graphs from different groups may be discussed. Another alternative is to have students do repeated testing with different number of the either same or different types of rubber bands. If this is done, the rubber bands should be hung parallel to each other from the ring stand and connected to the spring scale. If each rubber band is tested separately then combined with others, students could be asked to determine the relationship between the slope of the graph of individual rubber bands compared to the slopes of graphs when different rubber bands are combined.

The depth of preparation before students begin the lab may be as detailed as desired. However, as designed the specific information about Hooke's Law is very limited. Students are NOT encouraged or required to take notes at this point in time. This time is used to introduce the ideas behind the activity.

Pre Lab

1. An overhead with the statement: **Hooke's Law—the elongation of an elastic solid is directly proportion to the applied force** is shown to the class. Students are told to put the statement in everyday language. Students write down the interpretation on a sheet of paper. After a minute or so, students turn to a partner, share what is written then write a statement both agree with. After another minute or so, two groups combine and repeat the process. After the four students have written a statement, have a few teams read theirs aloud. Students may generate a statement such as: *"When an elastic object is pulled it gets longer. But it gets longer in a special way. The special way it gets longer is to get longer at a constant rate."*
2. Have students generate an ExD (Unit 6) for this lab. Since this is early in the semester they will need instruction, so it's a good idea to do this as a whole class discussion so students can become familiar with the format.
3. Introduce the lab to the students and review the equipment and set-up. This is a good time to review your safety rules and equipment policies.

During Lab

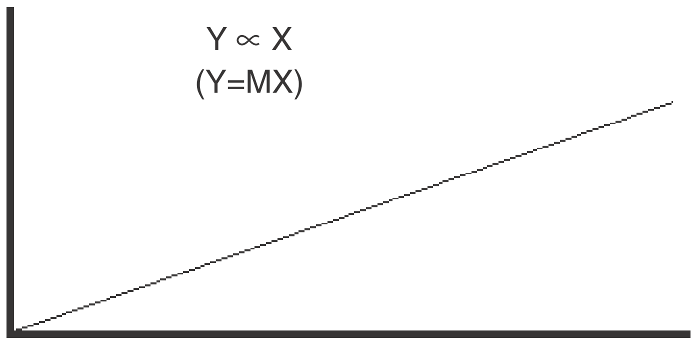
Monitor students working. Be sure they are aware of getting accurate readings. Consider having student lab team put their team data on the board, since anomalies will become clear if some lab teams are not getting 'good' data.

Post Lab

- The equation of the line of best fit for the rubber band should conform to one of a direct relationship, $y = mx + b$. The parts of the equation should be reviewed as to what is represented by each variable. The general shape of this and other standard graphical relationships should be reviewed or introduced (see Graphical Relationships diagrams). The sooner students learn to recognize and apply the appearance of a graph to the expected polynomial equation, the better students will understand and apply the concepts.
- After the graph and related information has been obtained, what it means should be discussed. The level of prior knowledge and understanding of graphs and equations will determine the level of discussion about what slopes are and represent.
- Analogies of stairs or hills compared to slopes will make sense to many students. Ask students to generate their own analogies and share as a class. Nearly all students seem to be taught in math classes that slopes are "the rise over the run." If this or other wording is commonly used in math departments, then use it as another common example in science classes.
- Have students generate a group lab report with a title page, ExD, Methods with a sketch of the apparatus, Results and Analysis (guiding questions in the student lab). Have groups report out their findings (speaking to learn).

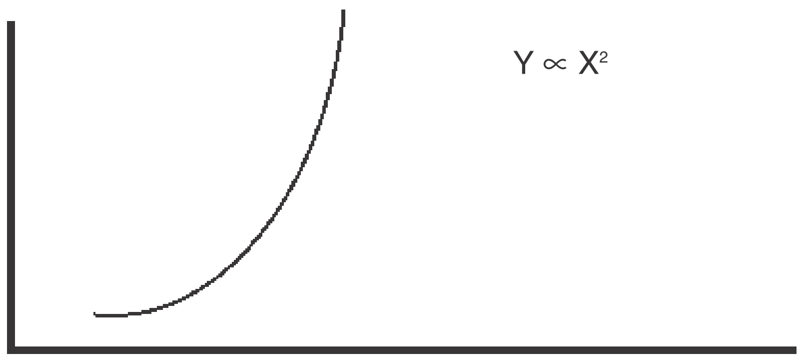
Graphical Relationships

Direct or Linear Relationship



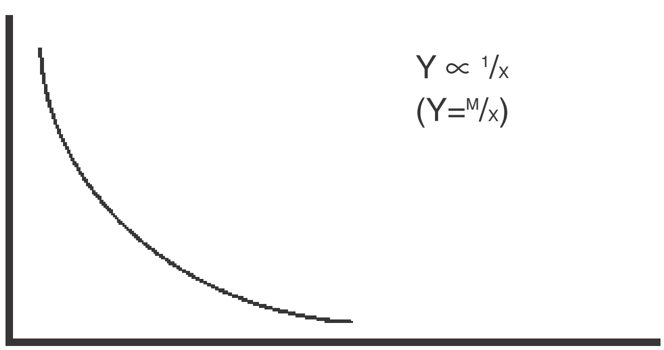
As one variable gets larger, the second variable also gets larger. The second variable gets larger at a constant rate.

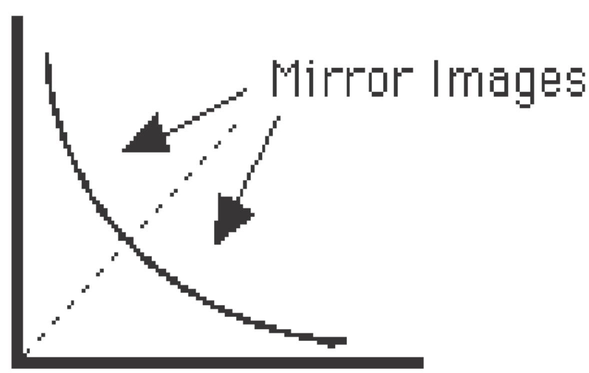
Squared or Exponential Relationship



As one variable gets larger, the second also becomes larger. The growth of the second variable is the square (or some other power) of the first variable.

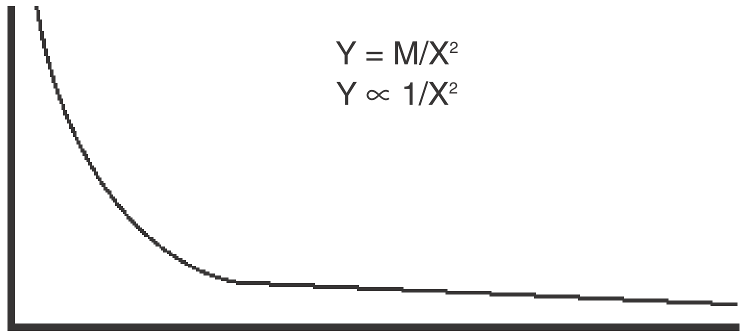
Inverse Relationship



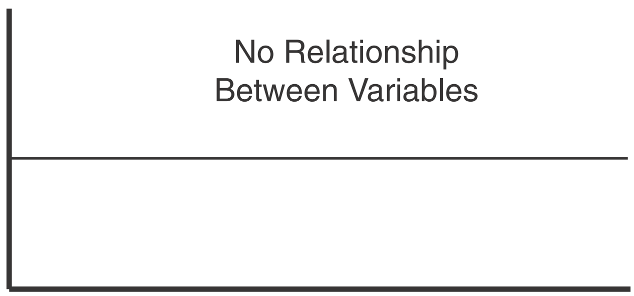


As one variable gets larger, the second becomes smaller. An easy way to recognize the relationship is to look at a diagonal line from the origin which bisects the curve. If two mirror images are obtained, the relationship is an inverse one.

Inverse Square Relationship



As one variable gets larger, the other becomes smaller. The graph is not symmetrical about a diagonal line from the origin.



As one variable changes, the other variable remains constant.

Safety Admonition

Follow all teacher and lab directions and handle rubber bands and equipment with caution.

Hooke's Law Lab

Question

Will a rubber band conform to Hooke's Law?

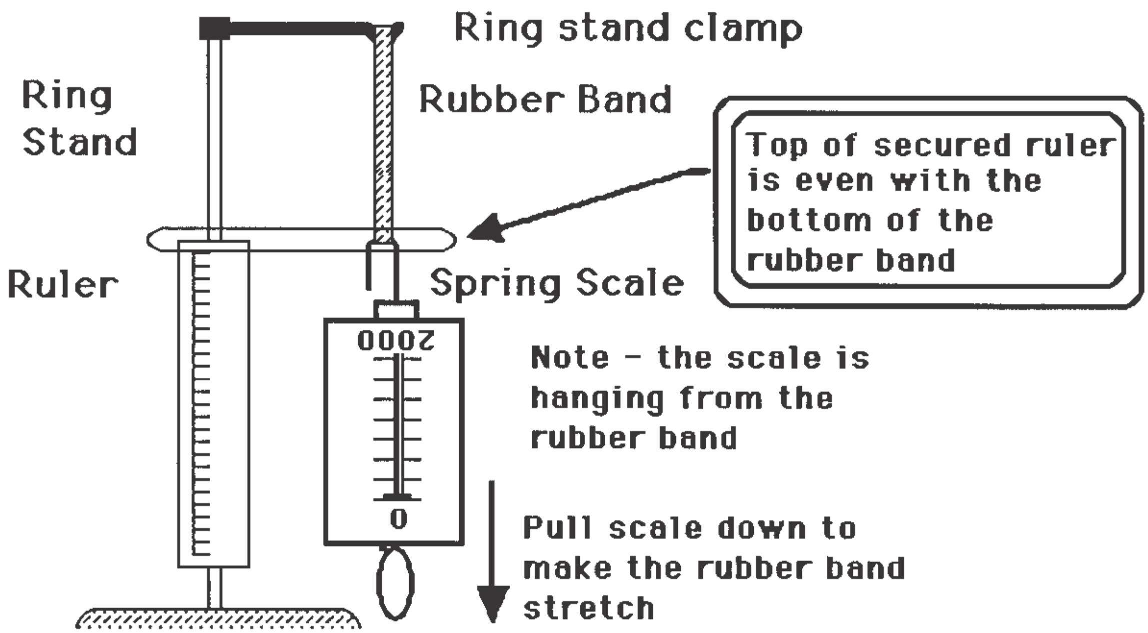
Materials

- Ring stand
- Metric ruler
- Rubber band
- Spring scale
- Graph paper

Methods

Set up the equipment as shown in the diagram.

1. *Student lab team HINT:* Start with the zero end of the ruler even with the bottom of the rubber band when the spring scale is hanging on the rubber band. This will allow the change in length of the rubber band to be easily determined.



2. At least ten different readings are needed over a range of 0 to at least 30.0 centimeters of stretch.
3. Pull the scale and take readings until the first of the following occurs: the scale is "maxed" out, the rubber band change in length reaches the length of the ruler or the rubber band breaks.
4. Measure then record the total distance the rubber band stretches from its original length and the reading on the spring scale.
5. Record your results in the data table below.

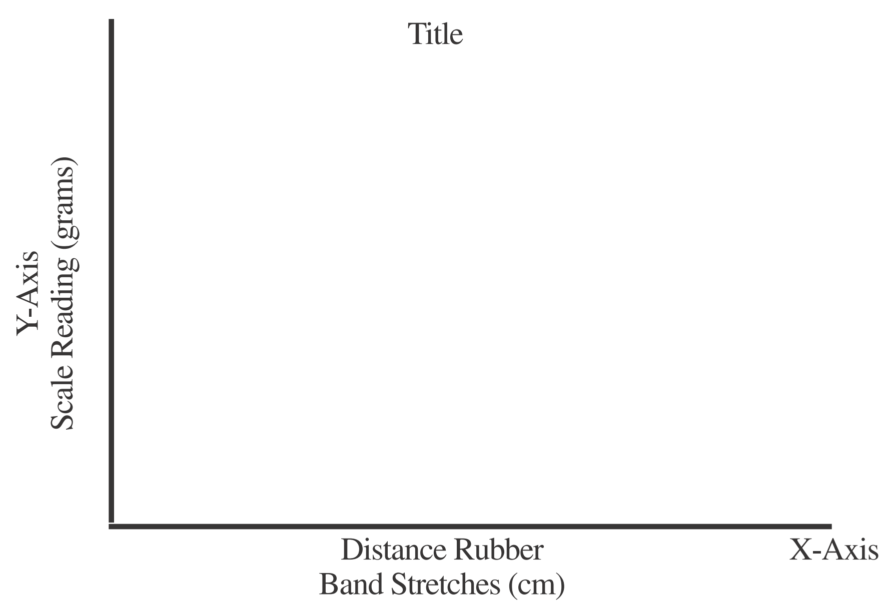
6. Results

Distance Rubber Band Stretches (cm)	Scale Reading (units)

Data Analysis

A. Graph the data:

1. Make a graph of the collected data.
   - Independent variable (x axis) = Distance Rubber Band Stretches
   - Dependent variable (y axis) = Scale Reading



B. Graphical information:

1. Use a graphical analysis program to plot the points then plot the line of best fit.
2. Determine the equation best describing the line of best fit.

Equation of the line of best fit: ______________________________

3. Use the equation to **predict** the scale reading needed to stretch the rubber band 22.3 cm.

Scale reading needed to stretch the rubber band 22.3 cm: ______________________________

4. Use the equation to predict the rubber band length when a scale reading of 3000 grams is applied.

Rubber band length when a scale reading of 3000 g is applied: ______________________________

C. Percent Differences

Use the following equation to calculate the percent difference between the predicted and actual measurements.

$$\textbf{Percent Difference} = \frac{100\,(\text{Actual - Predicted Value})}{\text{Predicted Value}}$$

- Percent difference between the scale readings: __________
- Percent difference between the distance stretched: __________

D. Analysis

In paragraph format, address the following points in compete sentences:

- Should the hypothesis be accepted or rejected? Explain why (include evidence).
- Identify the reasonable sources of error that may have taken place during the experiment. Explain how each source of error might have changed the results or interpretation of the data.
- The appearance of the graph most resembles what type of graphical relationship?
- What is the equation of the line of best fit? Explain.
- What was the percent difference between the predicted and actual scale readings?
- What was the percent difference between the predicted and actual distances stretched?
- Explain how the calculated percent differences help to determine if the relationship is, or is not, really linear.
- Use as much information from the experimentation and graph as possible to explain if the relationship between scale reading and distance stretched a truly linear.

If you did additional calculations with a computer graphing program then answer the following:

- What is the correlation coefficient of the graphed data?
- Explain what the correlation coefficient of graphed data represents.
- Explain what the correlation coefficient of YOUR graphed data indicates about the graphical relationship between the scale reading and the stretch of the rubber band.

Reaction Rivalry

Lab designed by Chris Dartland, Physics Teacher, Helix Charter HS, La Mesa, CA.

AP Discipline

Physics

Timeline

30–60 minutes

WIC-R Strategies

- Writing
- Inquiry
- Collaboration

Concept Statement

This lab presents a perennial favorite, the reaction time calculation, coupled with an experimental design that encourages competition and camaraderie. Students get ample practice with the position equation $x = x_o + v_o t + 1/2\ at^2$.

Lesson Plan

Before introducing this lab, students should be familiar with the concepts of motion, velocity and acceleration. They should have been introduced to concept of uniform linear motion under constant acceleration and the position equation above. Advanced students should be able to reduce the aforementioned equation to the form: $t = \sqrt{(1/2\ gt^2)}$, without the help of the instructor. They should also be able to use significant figures for measurement and calculation.

As an enrichment exercise, this straightforward lab can be used to introduce or practice experimental design. Some instructors may also wish to include statistical analysis of results.

Demonstrate the reaction time measurement by having a volunteer hold her thumb and forefinger about 4 cm apart even with the 0 cm mark of a metric ruler. To ensure more precision in measurement, mark a line on the midpoint of the volunteer's thumb. Drop the ruler to measure the distance of the fall. At this point it may be instructive to introduce the biological aspects of human reaction time (nervous system).

Next, explain that, as a class you would like to determine which gender has the fastest reaction time. If you are emphasizing experimental design, have students get in groups of two (preferably a boy and a girl) allowing 10–15 minutes to design the experiment.

Discuss the experimental design as a class. What other dependant variables could be explored using the same procedure?

Teacher Guidelines (2 of 2)

Have students run the experiment in mixed gender groups. They should calculate their reaction time for each trial, then, calculate an average reaction time for all trials (see the student Data Table included in this lesson). For additional practice with the equations of uniform motion, have students calculate the maximum velocity attained by the ruler in each trial ($vf^2 = v_o^2 + 2ax$).

Once students have completed this task, instructors may choose to have them post their average reaction times on a class data table. A "Box and Whiskers" plot can be used to analyze the data to see if either gender is the clear winner.

Sample Student Experimental Design

Title

Does a person's gender affect their reaction time?

Hypothesis

(Male/Females/Neither) will have a faster reaction time

Inedependant Variable

Gender of Participant

Description of groups	Male Participant	Female Participant
# of trials	5 trials per male	5 trials per female

Dependant Variable

Reaction time

Control

None (Comparison control to "normal" or class average)

Constants

- Same type of ruler (composition and mass)
- Consistent distance between thumb and forefinger (4 cm)
- Same gravitational acceleration (9.8 m/s^2)
- Same general age of participants (15–18 years old)
- Same lighting conditions

Reaction Rivalry

Question

Do males or females have faster reaction times?

Procedure

1. Observe the teacher's demonstration of reaction time.
2. Collect reaction distance data for five trials for you and your lab partner.
3. Perform reaction time calculations using the appropriate Equation of Uniform Linear Motion.
4. Show calculations with units for each trial.
5. Use significant figures when expressing your final reaction times.

$g = \text{m/s}^2$

Your Reaction Data

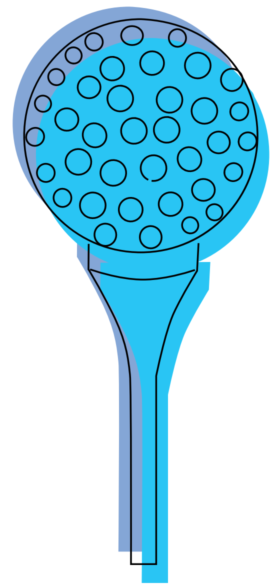
Reaction Distance (m)	**Reaction Time Calculation** Formula Used:	Reaction Time (s)
	t =	
	t =	
	t =	
	t =	
	t =	
	Average	

____***'s Reaction Data***

Reaction Distance (m)	**Reaction Time Calculation** Formula Used:	Reaction Time (s)
	t =	
	t =	
	t =	
	t =	
	t =	
	Average	

Golf Ball Labs

Lab designed by Martin Teachworth, Physics Teacher, La Jolla HS, San Diego, CA.



AP Discipline

Physics

Timeline

45 minutes per lab (three labs available)

WIC-R Strategies

- Writing
- Inquiry
- Collaboration
- Reading

Concept Statement

The following three golf ball labs allow the topic of motion, velocity, acceleration and the graphical relationships between displacement (distance), velocity (speed) and acceleration to be learned through experimentation and discovery. The labs may use any form of ball. They were originally designed to be used with bowling balls rolled down ramps made of 2 x 4 boards, however golf balls work well too. The labs are sequential, simple, straightforward and allow a wide range of concepts and relationships to be explored.

Lesson Plan

Appropriate to use during the unit on velocity and acceleration. Do the Golf Ball Lab one first. Determine the average velocity using V = d/t (velocity = distance divided by time) The velocity equals the meters traveled divided by the time recorded. The velocity has the units of meters/second (m/s). Do Golf Ball Lab Two next. The slope of the graph should be a constant. The slope will be equal to the average velocity. Determine the average velocity using V = d/t (velocity = distance divided by time) The velocity = the meters divided by the time recorded. The velocity has the units of meters/second (m/s).

Teacher Prep and Hints for Success

- Collect the needed materials as per the student lab sheets.

Lab 1: The teacher should be the controller of the stopwatch for labs one and two. Start the stopwatch when the ball first hits the ground NOT when it is first released on the ramp. If this is not done, then the average speed will include the acceleration down the ramp. All the data for the class will tend to be the same, as it should be, and explaining what was recorded will be easier.

— On labs two and three consistent and accurate timing of the ball on the shorter distances will be difficult if not impossible to do. This is an important reason for the teacher to do the timing. If the time appears to be off, then the roll should either be redone, or the teacher can approximate what the value should be based on rolls of other balls. All the balls of the same type will have similar times for the same distance.

— Instead of five rolls, fewer rolls per distance could be used. This will decrease the time needed to do the testing.

— The teacher should be positioned at the appropriate mark on the floor. When the student releases the ball begin timing when the ball strikes the floor. The student roller should then move to the back of the line. The recorder should record the time read off. The student stopper stops the ball, and the ball return person brings the ball back to the front of the room. When all teams have cycled through the distance being used, then the teacher moves back to the next distance and the process is repeated until all the distances are done.

— After all the data is collected, then the class as a whole can be shown how to do the calculations. By lock-stepping the students, there will be less confusion as to what is to be done and how to do it.

Lab 1: Keep the same release points for all students. Release is the very top of the ramp. Life will be much simpler if all groups release the ball from the same point. The velocity determined at this point should be recorded and kept for the next lab.

— An average velocity is the velocity over a long period of travel. An instantaneous velocity is the velocity at any instant of time. A speedometer shows the instantaneous velocity. For example, a trip to Disneyland may take 3 hours to go 120 miles. The average velocity is 40 miles/hour, but the velocity varies from 0 to the fastest velocity (60, 70, 90 mph) traveled during the trip.

Lab 2: To measure the instantaneous velocity using a stopwatch and meter tape, a very short distance, and the time it took the ball to travel that distance would have to be measured. The problem with this is the reaction time of the person measuring the time. The reaction time of a person is at best about 0.1 seconds. Anything measured by humans must take this into consideration.

Lab 3: Do the Golf Ball Acceleration after the first two. Take the ramp and table out to a grassy or sandy area. Release the ball from the top point on the ramp that all students will use to record the velocity from the second golf ball lab.

— Students record the distance the ball rolls from the base of the ramp. Set a tape measure next to the path the balls take, to allow students to quickly and easily measure then record the distance. The rolling of balls for the lab should take no more than 15 to 20 minutes. As soon as the ball is rolled, have students measure and record then get into line to roll the ball again.

— The instantaneous velocity at the base of the ramp is the average velocity recorded from the second Golf Ball lab. The assumption is made that the ball's acceleration (a negative acceleration) is constant over the entire length of travel. While this may not be entirely correct it allows the motion equations assuming a constant acceleration to be used.

Teacher Guidelines (3 of 3)

To determine the acceleration the equation, $V_f^2 = V_o^2 + 2\,a\,x$ is used. The value of V_f is zero meters per second. This is the final velocity of the ball after it has finishing rolling. The value of V_o is the velocity recorded from the first lab. This is the velocity of the ball when first rolling on the grass. The value of x is the distance the ball rolls on the grass.

The final form of the equation after the algebra has been done will be:

$$a = \frac{V_f^2 - V_o^2}{2\,x}$$

Since V_f is zero, the equation changes to:

$$a = \frac{-V_o^2}{2\,x}$$

The negative acceleration just means that the ball is slowed until it stops.

During Lab

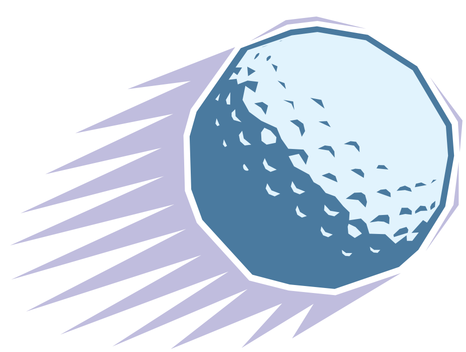
See the points noted above for clarification and suggestions.

Post Lab

Discuss each of the lab calculations and findings before beginning the next. The last lab, *Golf Ball Acceleration & T-WOODS Corporation,* is intended to build on the other two and gives students a simulated situation to put the golf ball learning in a context. As a final product, student teams should compile the results of the three labs in a Lab Report, each with their calculations, graphs and analysis questions, and complete the final analysis section in a paragraph format. Student lab teams can be selected for each one of the three labs to walk the class through the calculations and graphs and lead the discussion (see Unit 4, Talking to Learn.)

Safety Admonition

Follow all directions. Discuss proper use of golf balls and share consequences for inappropriate behavior during this lab.



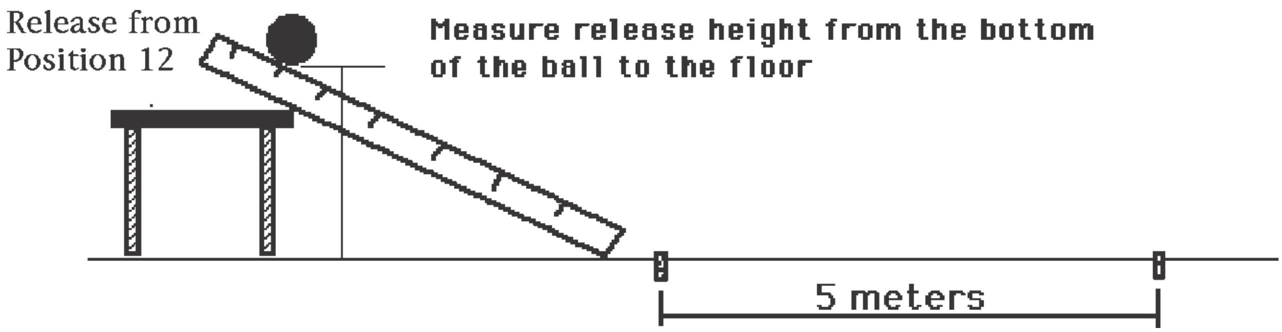
Golf Ball Lab One - Average Speed

Question

How can average speeds be determined?

Materials

- Ramp
- Meter stick
- Books or VERY low table
- Stop watch
- Golf ball
- A smooth floor



Methods

Mark off a 5 meter distance on the floor from the base of the ramp.

1. Place the bottom of the ball on the top mark on the ramp.
2. Release the ball.
3. Start the timer when the ball reaches the floor.
4. Stop the timer when the ball crosses the mark at 5 meters.
5. Complete the data table with at least 5 trials and calculate the average.

Results

Release Position	Total Time (seconds)	Average Speed (m/s)
12		
12		
12		
12		
12		
Average		

Finding the Average Speed

Calculate the Average Speed using the equation below:

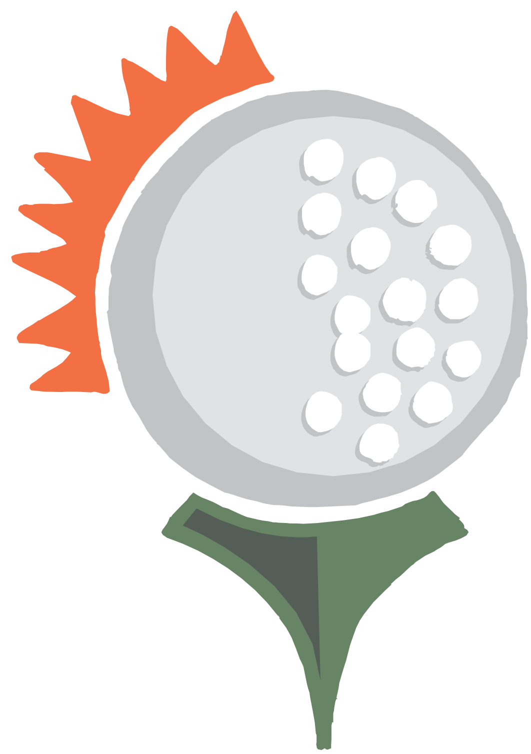
$$\text{Average Speed} = \frac{\text{Distance Traveled}}{\text{Time}}$$

Analysis Questions

1. What formula was used to determine the average speed of the ball?

2. Explain the difference between an average speed and an instantaneous speed.

3. How could the lab procedure be modified, using the same equipment, to obtain a speed of the ball as it passed a point exactly 2.00 meters from the base of the ramp?



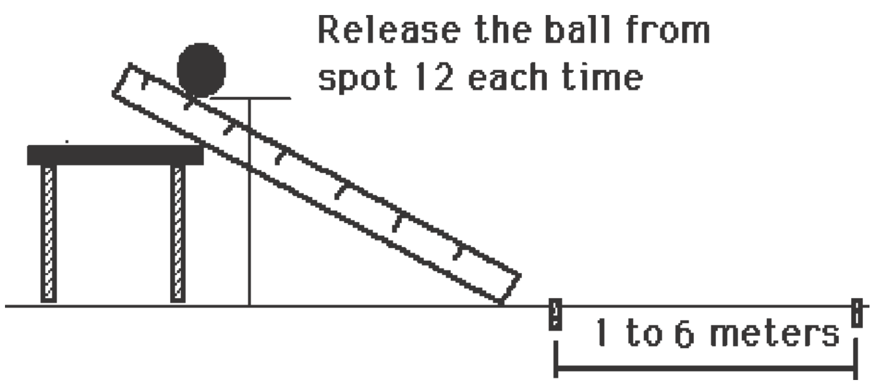
Golf Ball Lab Two: Introducing Speed Through Graphing

Question

How are distance, time and speed related?

Materials

- Golf ball
- Stop watch
- Ramp
- Tile floor
- Books or VERY low table



Methods

1. Release the ball from spot 12 on the ramp.
2. Start the timer when the ball hits the floor.
3. Stop the timer when the ball passes the distance marker.
4. Repeat the testing four more times for each distance then move on to the next distance.

Results

Distance and Time Measurements

Meters (m)	Time (s)	Time (s)	Time (s)	Time (s)	Time (s)	Average Time (s)	Average Speed (m/s)
1.00							
2.00							
3.00							
4.00							
5.00							
6.00							

Overall Average________________

Calculations

To calculate the average speed, use the equation

$$\text{Speed} = \frac{\text{DISTANCE}}{\text{TIME}}$$

Analyzed Results

- Graph (on graph paper) the Time (IV) on the X axis versus the Distance (DV) on the Y-axis. Plot the points then draw a line through the center of the points.
- **Option**: Use the computer to plot the graph. Find and draw the regression line, the values for the slope (m), y intercept (b) and correlation coefficient (R). The slope (m) should be the close to the average speed.

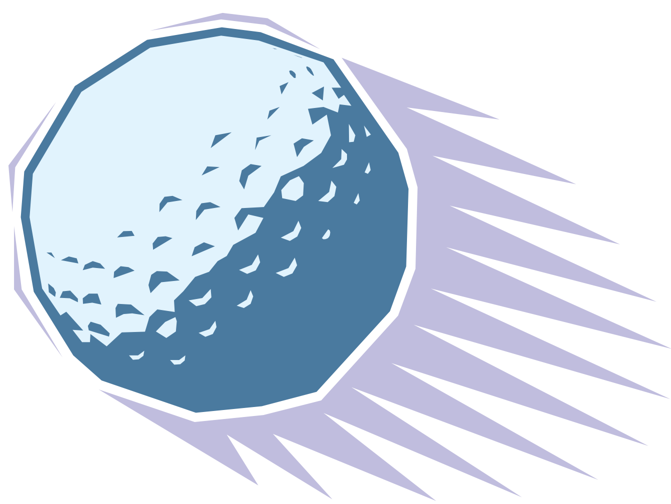
Analysis Questions

1. What was the overall average speed?

2. What was the slope of the graph? What type of slope is it?

3. Explain how the slope of the graph and the speed are related.

4. What sources of error may have influenced your results?



Golf Ball Acceleration & T-WOODS Corporation

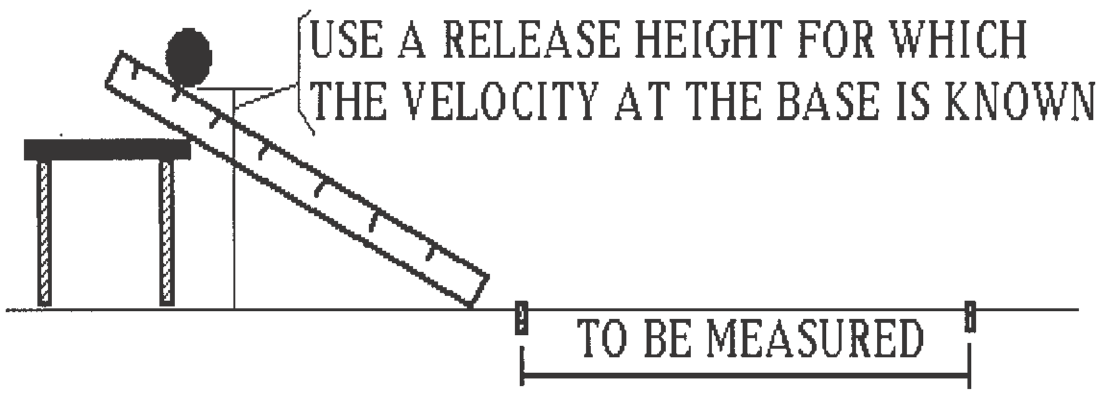
Congratulations! You have just been hired as the new engineer on golf ball acceleration for the new T-WOODS Corporation, Ltd. It is of great importance that the golf balls your company produces be speedy and become world famous. As a public relations move on the part of T-WOODS, you are being asked to instruct a class of young, but successful, junior golfers. You decide to explain the physics of golf ball acceleration, but before you teach the junior golfers, you have to brush up on your own skills, since your boss will be watching. You decide to construct an ExD, since it will help you explain the independent and dependent variables and to state a working hypothesis.

Problem

Can both the average and instantaneous acceleration of a ball be determined?

Materials

- Ramp
- Meter stick
- Outside area for experimentation.
- Books or VERY low table
- Stop watch
- Golf ball
- Graph paper



Methods

1. Submit an ExD to your "boss" for approval.
2. Release the ball from a height for which the velocity at the base is known (use data from a previous lab, or it will be given to you by your "boss"). Be sure the testing area is as flat as possible.
3. Time how long it takes the ball to roll each distance.
4. Measure the time for every meter until the ball stops rolling.
5. Determine the total distance and the total time the ball rolled before stopping.
6. Complete the data table (or design one of your own).

Results

Remember, you'll need the following in order to show how to do the calculations!

Initial velocity at the base of the ramp _________ m/s

Final velocity at end of rolling ___________ m/s

Distance and Time Measurements

Meters (m)	Time (s)	Time (s)	Time (s)	Time (s)	Time (s)	Average Time (s)
1.00						
2.00						
3.00						
4.00						
5.00						
6.00						
7.00						
8.00						
*						

** Continue data table until the ball comes to a complete stop.*

Total Distance and Time the Ball Rolled from the Base of the Ramp

Total	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Average**
Distance Rolled						
Time Rolled						

Calculations and Analyzed Data

Part I

Make a graph (on graph paper) of the Time (IV) on the X axis versus the Distance (DV) on the Y axis. Plot the points then draw a line through the center of the points. *Reminder*: The line should curve and not be a straight line.

Optional Analysis

Use the computer to plot the graph. Find and draw the regression line, the values for the slope (m), y intercept (b) and correlation coefficient (R). The slope (m) should be the closest to the average speed. *Reminder:* Do not use a simple curve fit, use a polynomial curve fit.

Part II

a. Determine the *Average Acceleration* of the Ball After It Leaves the Ramp

$$\mathbf{V_f^2 = V_o^2 + 2\,a\,d} \text{ \textit{so} } \mathbf{a = \frac{V_f^2 = V_o^2}{2\,d}}$$

V_f^2 = the final velocity squared, when the ball stops rolling. It is zero meters per second.

V_o^2 = the original velocity squared (how fast the ball is rolling at the bottom of the ramp)

b. Use the equation below to find the average acceleration for the trip.

$$a = -\frac{\text{Velocity at the bottom of the ramp squared}}{2\,(\text{maximum distance rolled})}$$

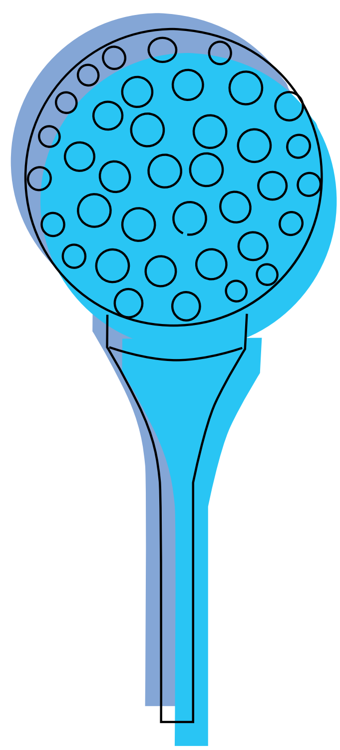
AVERAGE ACCELERATION= _______ m/s²

(Note: this will be a negative acceleration or a deceleration)

Analysis questions to be addressed in the report to the boss:

Include the ExD and your Results sections (calculations and graph) and using a paragraph format, address the following points. Then submit the final report and wait for your raise.

- What was the velocity of the ball at the base of the ramp?
- What formula was used to determine the average ACCELERATION of the ball?
- Why is the average acceleration on the outside area a negative number?
- Explain why the average of the data points on the graph is not a straight line.
- How could the graph be used to determine the speed of the ball at any point of travel?
- Explain the difference between an average and an instantaneous velocity.
- Explain how to recognize acceleration on a displacement versus time graph.
- Why is any of this important for golf balls to function well?



DC Circuit Design

Lab designed by: Chris Dartland, Physics Teacher, Helix Charter HS, La Mesa, CA.

AP Desciplines

Physics

Timeline

1 hour

WIC-R Strategies

- Inquiry
- Collaboration

Concept Statement

The vast majority of students who pursue Physics at the college level will use their knowledge in a design application. This lab seeks to give students parameters to design a relatively simple DC circuit. If electrical equipment is available, and time permits, the instructor may wish to have students build and test their designs.

Lesson Plan

Before attempting this lab, students should be familiar with the mathematical statement Ohm's law for parallel and series DC circuits, calculation of electric power, and the common symbols used in basic electric circuit schematics. Students should have had the opportunity to build basic series and parallel circuits so that they clearly understand the difference between the two configurations.

The lab asks students to design a dependable circuit for automobile headlights and taillights. It also should include at least one other component such as a windshield wiper motor. Instructors may wish to modify the lab to include other components, such as brake lights, in the design prompt for a more realistic and challenging application.

Pre Lab Discussion

- Discuss the operation of a basic automobile headlight/taillight system. Ask: What happens if they are driving and one headlight goes out? Does the other headlight continue to operate? Is this also true of the taillights?
- Next review the concept of breakers and fuses. Make sure that students understand that the fuse should protect one component of the system (e.g., taillights) from a surge of current. A 50-cent fuse can easily save $30 worth of headlights in the event of a power surge.
- Finally, make sure that the students understand that a single switch operates both the headlights and the taillights, while another switch operates the wiper motor.

During Lab and Post Lab Suggestions

Students will invent such a variety of circuits that it can easily overload the instructor. Make sure that they understand that the circuits must be **dependable**, thus leading them to a parallel circuit design without actually telling them to use a parallel configuration. Success in an open-ended design lab depends upon perseverance. Instructors may want to group students whose skills will be complementary in the pursuit of this goal.

Safety Admonition

Follow all lab directions. Do not touch bare wires while completing circuits. Use caution handling glass light bulbs.

Electric Circuit Design Lab

Purpose

To design a dependable electric circuit for a 12-volt direct current automobile electrical system.

The circuit must include the following:

- Two headlights which have one fuse for both
- Two taillights which have one fuse for both
- A windshield wiper motor with its own fuse
- A switch that operates **all** four the lights
- A switch that operates the wiper motor

Each component has the resistance listed below

Headlight	R = 2.0 Ω
Taillight	R = 4.0 Ω
Wiper motor	R = 1.0 Ω

Procedure

1. Sketch drafts of your circuit design.
2. Draw your final design on a piece of graph paper.
3. Label each component.
4. Perform the calculations for the Analysis Section below.
5. Label and color code the current in each conductor.

Analysis

Show all calculations below

1. What is the voltage in each branch of the circuit?

   Ans. 12 V
2. Determine the current through each headlight.

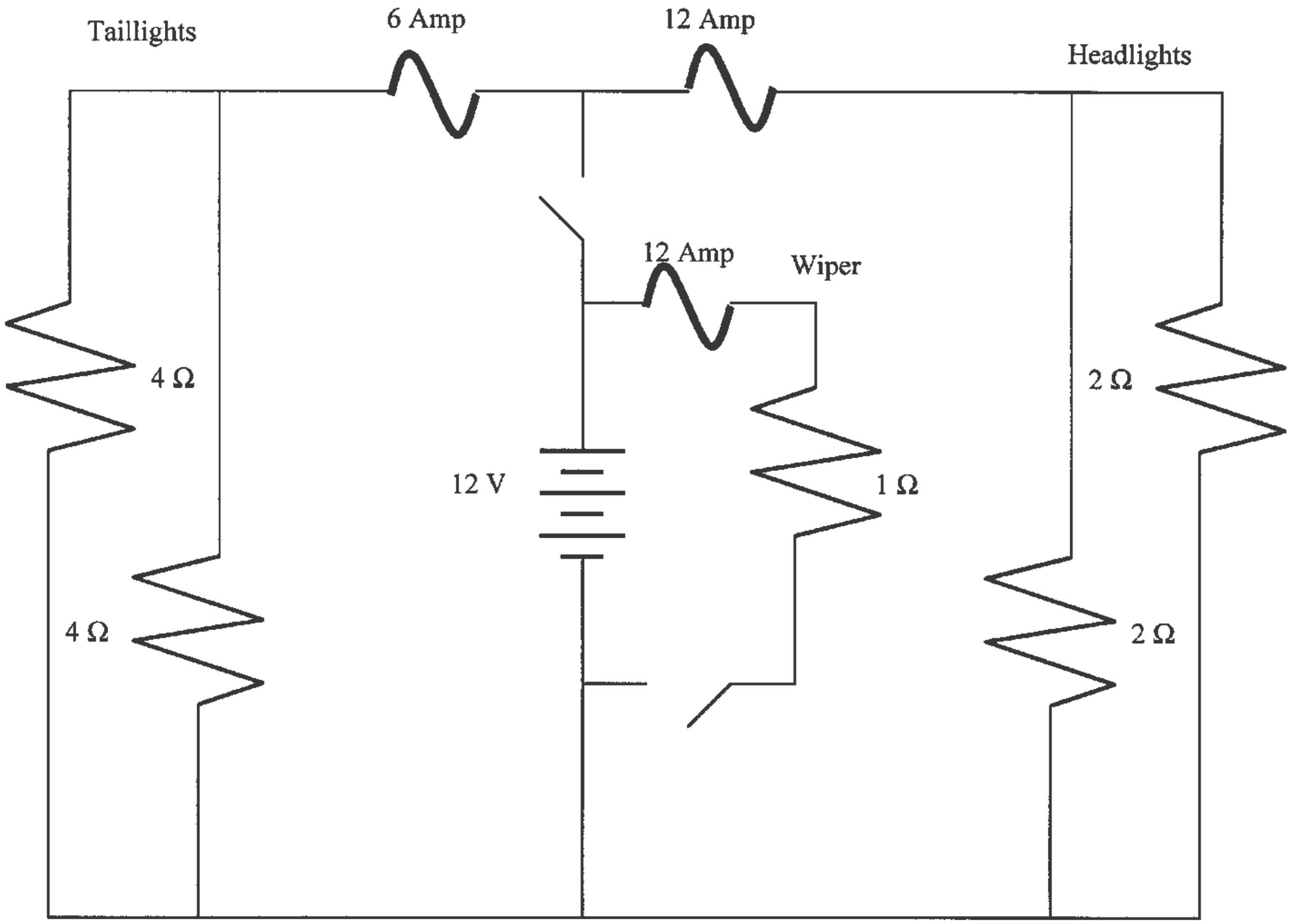
   Ans. I = V/R = 12V/2.0 Ω = 6Amp
3. Determine the current through each taillight.

   Ans. I = V/R = 12V/4.0 Ω = 3Amp
4. Determine the current through the wiper motor.

   I = V/R = 12V/1.0 Ω = 12Amp

On your drawing, label the proper fuse size needed for each part of the circuit
(See Sample Circuit, on the next page).

Sample Circuit Design Solution



Electric Circuit Design Lab

Lab Team Names: ____

As a newly hired automotive electrical design team member, your experienced supervisor wants to make sure you all "know your stuff" and can work effectively together. Your team is given the following problem and you are also being timed, because in the real world, time is money. Demonstrate your skills by solving the problem below. Don't forget to note the steps you took and the calculations you made along the way. Impress your new boss!

Problem

What is required to design a **dependable** electric circuit for a 12-volt direct current automobile electrical system?

Project Requirements

The circuit must include the following:

- Two headlights which have one fuse for both.
- Two taillights which have one fuse for both.
- A windshield wiper motor with its own fuse.
- A switch that operates **all** four the lights.
- A switch that operates the wiper motor.

Hints for Designers: Each component has the resistance listed below

Headlight	$R = 2.0\ \Omega$
Taillight	$R = 4.0\ \Omega$
Wiper motor	$R = 1.0\ \Omega$

Evidence Needed by the Supervisor

1. Sketch drafts of your circuit design and summarize each briefly.
2. Draw your final design on a piece of graph paper (rulers!)
3. Label each component neatly.
4. Perform the calculations for the Report to Supervisor section below.
5. Label and **color code** the current in each conductor.

Supervisor Report

Show all calculations below, or take a pay cut.

- What is the voltage in each branch of the circuit?
- Determine the current through each headlight.
- Determine the current through each taillight.
- Determine the current through the wiper motor.

On your drawing, clearly **label** a proper fuse size needed for each part of the circuit (All team members sign that they agree with the final product.)

Friction Under Pressure

Lab designed by: Chris Dartland, Physics Teacher, Helix Charter HS, La Mesa, CA.

AP Disciplines

Physics

Timeline

2 hours

WIC-R Strategies

- Writing
- Inquiry
- Collaboration

Concept Statement

This lab takes a relatively simple procedure for calculating coefficients of static and kinetic friction and allows students to investigate the effects of pressure on experimental outcomes.

Lesson Plan

Students should be familiar with Newton's Laws, the basic definition of Pressure = (force/Area), Force Vector Diagrams, and the calculation of Coefficients of Static and Kinetic Friction. Students should also have had previous experience creating an experimental design.

Teacher Preparation

This lab can be executed with inexpensive everyday materials as described below. Instructors can easily make substitutions to include materials they have available.

Cut a regular 2" x 4" piece of lumber into 6" or 8" sections so that there is one for each lab group. Make sure any splinters are removed from the smooth surfaces of the block. Attach an eyehook to each one at the center of the cut (rough) surface.

A class set of five Newton spring scales, or electronic force sensors will be needed for the lab.

A balance will be needed to determine weight and thus the normal force.

Various surfaces to drag the wood blocks on should be available. In addition to lab tables and the classroom floor, concrete, and asphalt are usually nearby the classroom. Carpet, doormats or even mouse pads can be used as additional surfaces.

Various masses should also be made available as another means to increase pressure on the blocks.

Pre Lab Activities

The class should be prompted with the following question: Are the coefficients of friction between two surfaces affected by the pressure between the two surfaces? The answer to this question for most ordinary surfaces in contact is "No." Although this result is not intuitive, the equation $\mu_S F_N = F_S$ and its Kinetic counterpart $\mu_k F_N = F_k$ tell us that the friction force between ordinary surfaces is dependant only upon the two surfaces in contact.

Advanced students should be able to design their own experiment based upon the materials available. It may, however, be instructive to discuss with students that the maximum static friction force is the maximum reading on the scale before the object (wooden block) begins to move. Additionally, kinetic friction force is the maximum reading on the scale when the object is moving at a constant velocity, i.e., there is no net force on the object. These concepts can be illustrated using a Force Vector Diagram.

Lab

Experimental Design

Have students form groups of two to prepare their experimental design (see sample provided). The instructor may choose to assign one student in the group to be responsible for experimentation involving static friction while the other student explores kinetic friction. Check these before allowing students to proceed with the lab.

There are two similar approaches to varying the pressure. In one case the same surface can be used and additional weights can be added to increase the pressure. Or, the surface area (side of the wooden block) can be varied with or without a variation in the weight of the experimental set up. The instructor may wish to specify a minimum number of experimental groups.

Experimental Procedure

This lab affords an excellent opportunity for students to develop their technical writing skills. Students should easily be able to list the materials needed for the experiment. A procedure or methods section should consist of a set of numbered steps written as commands. Procedures may vary considerably for valid experiments. A sample procedure is provided.

Data

In an open-ended lab such as this, students are expected to design a data table appropriate for their own experimental procedure. A sample data table is provided.

Calculations

For ease of evaluation, students should create a complete set of sample calculations.

Analysis

To conclude the lab report, have students write a multi-paragraph analysis that cites specific data in order to support (or not support) their hypothesis. Emphasize that they will not "prove" that their findings are valid.

Safety Admonition

Common sense must prevail for this project. Be careful with the blocks and other materials. Follow all lab directions.

Sample Experimental Design for Friction Lab

Title

Does the pressure between two surfaces affect the coefficient of Static (or Kinetic) friction?

Hypothesis

Increasing pressure between two surfaces will(increase/decrease/not affect) the coefficient(s) of friction.

Independent Variable

Pressure between the two surfaces (Weight to Surface Area ratio)

Dependant Variable

Coefficient of Static Friction or Kinetic Friction

Description of Groups	4" x 8" surface wood/tile floor	2" x 8" surface wood/tile floor	4" x 8" surface wood/cement	2" x 8" surface wood/cement
Number of trials	5	5	5	5

Control

Published Standard Values of coefficients of friction for various surfaces (if available).

Constants

- Same force measurement device
- Consistent smoothness on different surfaces of the wood block
- Consistent temperature
- Consistent humidity

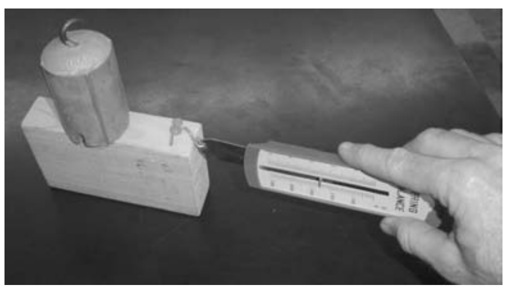
Sample Experimental Procedure

1. Place a wooden block so that its largest surface is in contact with a clean level section of the floor.
2. Place a 1.0 kg mass on top of it.
3. Attach a 5N spring scale to the side using a push pin or eye hook as shown in *Figure 1*.
4. Pull until the block begins to move noting the maximum reading on the scale. This is equal in magnitude to the static friction force.
5. Record data.
6. Repeat steps 1–5
7. Average the values of static friction force obtained.

Figure 1

8. Repeat steps 1–7 with the block on its side as shown in *Figure 2*.

Figure 2



9. Repeat steps 1–8 for the wood block on a clean level cement surface.
10. Determine the mass of the block setup on a balance. Record data in kilograms.
11. Calculate the normal force between the block and the table. $F_N = W = mg$.
12. Calculate the average coefficient of static friction using the average static friction force for each configuration and the equation $\mu_S = F_S/F_N$.
13. Determine the surface area in meters squared of each block face in contact. surface area = length x width.
14. Determine the pressure of each configuration in N/m^2. $P = F_N/A$.

Sample Data Tables

		Static Friction Force (N)		
Configuration	4” x 8” surface wood/tile floor	2” x 8” surface wood/tile floor	4” x 8” surface wood/cement	2” x 8” surface wood/cement
Trial #1				
Trial #2				
Trial #3				
Trial #4				
Trial #5				
Average				

Configuration	4” x 8” surface wood/tile floor	2” x 8” surface wood/tile floor	4” x 8” surface wood/cement	2” x 8” surface wood/cement
Mass (kg)				
Normal Force (N)				
Average Coefficient of Static Friction				
Surface Area (m^2)				
Pressure (N/m^2)				

Friction Under Pressure

Question

Does friction vary with pressure? Or more specifically, are the coefficients of static and kinetic friction affected by pressure?

Materials

- Wooden blocks with eye hooks
- Balance
- Various masses
- Metric ruler
- 5N spring scales
- Various clean level surfaces

Your Job

Form lab groups of two. One person will explore Static Friction while the other explores Kinetic Friction.

Each student will be responsible for the following:

- An Experimental Design
- A step by step procedure for your experiment
- A completed data table
- A complete set of sample calculations reflecting the precision of the measuring instruments. Use significant figures for all calculations!
- A lab report including an analysis in which you cite specific data to support or not support your hypothesis.

Warning

As you collaborate and collect data, your experiments will likely be very similar. Be careful that your analysis section is entirely your own work and reflects your own thinking.

UNIT 8: DOING RESEARCH IN SCIENCE

Overview

In college level science courses, students are expected to know how to develop and present scientific information appropriately in research reports. However, science teachers typically have precious little time to devote to writing longer pieces about science let alone helping students to research the topic. As science teachers, we need to be advocates for our students by teaching them how to research for scientific ends.

Science research can be divided into two basic types of projects. First, there is the research paper. The paper can vary in length from a few paragraphs to many pages, depending on the level and intent of the paper. These parameters must be set in the directions you provide to students. Typically, the second type is a research-based science fair project which often requires a research paper. Too few students see the connection between reading extensively to understand what is already known about a topic and developing a good science fair project. The key with both types of research is that students need guidance to set clear parameters on their topics and to access information.

Research projects are difficult for many reasons. By organizing research papers into smaller steps, students feel more successful because they are building a paper rather than throwing one together. In other words, it all comes down to organization. This unit looks at how to help students define their topic so that it fits the assignment whether it is a science project or research paper and helps students identify and seek out resources for their research. The unit also demonstrates how to evaluate information for scientific validity, based on several criteria, and discusses how to document with citations and organize references. Finally, the unit outlines how students summarize work in an abstract, a key scientific tool. The last two activities provide ideas for science research projects.

California Content Standards Addressed

Investigation and Experimentation 1. l and m

Selecting A Topic

Timeline

30 minutes of class time; varies by student outside of class 30–90 minutes

WIC-R Strategies

- Writing
- Inquiry
- Collaboration
- Reading

Concept Statement

The activity in this lesson provides direction for helping students to develop an apporpriate research topic.

Lesson Plan

This lesson is to be introduced at the onset of the research paper or project.

1. Briefly introduce the research paper or project with the timeline and requirements. Review all of the Student Handouts for these activities.
2. Model selecting a topic in class with several students using the Student Handout "Selecting a Topic." First, ask a student about his/her interests. Work with the student to develop four questions as directed by the activity. Repeat this procedure for three other students, one interest each. As students get the idea, they can begin to work individually or in small groups. Have students complete their lists outside of class.

   An alternative way to model this is through a class lab designed by the students. Introduce a topic like solubility. Ask the students what they think will affect the rate at which a solid will dissolve in a liquid. Get a range of ideas like temperature of the liquid, stirring the liquid, the type of liquids, etc. Demonstrate how to pose questions for these ideas. How does changing the temperature of the liquid affect the rate of dissolution?
3. Have students complete steps 2–4 as the instructions state. This ensures that topic ideas stay in the "doable" arena. Students should then choose the question that they are most interested in researching and submit on the project "Approval Form." When students turn in their research question, make sure to collect their topic list as well. With the topic list in hand, you can steer them towards a more appropriate topic if their first choice is inappropriate.
4. Next, have students review the criteria for a testable hypothesis (see "Selecting a Testable Hypothesis"). Have students write a hypothesis for their research question that meets all of the criteria. Submit the approval form to you.
5. As you read project questions and hypotheses, revise student work for grammar and wording as necessary. Approve good topics and ask for revisions on poor topics. Make comments to help students improve their topic selection. Spending time helping students pick solid, doable topics will payoff later when doing research. Be sure to deny topics that are unacceptable for safety, school policy, ethical or other reasons. No one wins when a student chooses a topic that they will not be able to complete.

Selecting a Topic

The hardest part of any project is to develop the idea or the topic. To simplify, you might begin by reading past research ideas. Good sources of past research can be found at local universities. These mainly include old master's degree theses and scientific journals (e.g., *Scientific American*). Other sources include reading the guide for past Science Fairs and books or Internet sites that have ideas for science projects. While you cannot do the exact project from these sources, you can twist the variables to create a new experiment.

This research project requires you to find current research and to complete an experiment. Be sure to select a topic that is affordable and doable in time and space. Remember, you must also write a five-page background information section. This means that you must find current research on this topic at the library, so choose a topic carefully.

Directions for selecting a topic:

1. List five topics in which you are interested on the numbered lines on the "Research Interest Inventory Form." Remember, your experiment must have a minimum of two experimental groups: one with the treatment and the other without.
2. Cross out all topics that are unacceptable according to the list in the project guidelines.
3. Cross out all topics that would involve experimentation that you could not complete in six weeks. Cross out all topics that would be too expensive OR that you do not have the equipment to complete. (If you have no more topics left, return to the list and choose five more. Repeat steps 3–5.)
4. Of the remaining topics, write at least four research questions about your topic that could be answered by the experiment that you intend to do. Choose the one that is the best of the three.
5. Write your research question on the "Research Question Approval Form."
6. Write a hypothesis in the "If... , then..." format on the "Research Question Approval Form." Be sure to review "Developing a Testable Hypothesis."
7. Discuss with your current science teacher before the topic deadline arrives. Your current science teacher must sign the "Research Question Approval Form."

Example: Topic/Interest #1: Brass Instruments

a. Does the type of lubricant on a trombone make it easier to slide the slide?
b. Does the thickness of the brass affect the pitch of the instrument?
c. Does the length of the slide affect the sound of the trombone?
d. Does the size of the mouthpiece affect the sound of the horn?

This student chose "Question a" as his research question. The hypothesis was "If cold cream is used as a lubricant on a trombone slide, the trombone slide will move more easily."

Reminder: **You are required to develop at least four research questions (list them on the "Interest Inventory") and submit for approval.**

Research Interest Inventory Form

Interest #1 ______________________________

Question a: ______________________________

Question b: ______________________________

Question c: ______________________________

Question d: ______________________________

Interest #2 ______________________________

Question a: ______________________________

Question b: ______________________________

Question c: ______________________________

Question d: ______________________________

Interest #3 ______________________________

Question a: ______________________________

Question b: ______________________________

Question c: ______________________________

Question d: ______________________________

Interest #4 ______________________________

Question a: ______________________________

Question b: ______________________________

Question c: ______________________________

Question d: ______________________________

Interest #5 ______________________________

Question a: ______________________________

Question b: ______________________________

Question c: ______________________________

Question d: ______________________________

Research Question Approval Form

Name: ______________________________ Due: ______________

This form must be completed and your current science teacher must approve your topic. Keep your approved topic in binder with all other project requirements.

Research Question:

____

____

____

Hypothesis: If/When ______________________________

____

Then ______________________________

____

____

Do not write in the box below.

Question and hypothesis are approved.

Current science teacher's signature ______________________________

Question and/or hypothesis require revision. Resubmit by ______________________________

Current science teacher's signature ______________________________

Question and/or hypothesis unacceptable. *See your teacher.*

Revised research question: ______________________________

____

____

Revised hypothesis: Revised question and hypothesis approved.

If/When ______________________________

____

Then ______________________________

____

____

Current science teacher's signature ______________________________

Revision still required. *See your teacher.*

Developing a Testable Hypothesis

Scientific methods and experimentation usually depend upon observations by the scientist. After making observations, the scientist thinks about what could be happening to cause the observation or what effect the observation would have on another factor. The scientist then forms a **hypothesis**, or an educated guess, about the observation. An experiment is designed that will test whether or not this hypothesis is correct.

The hypothesis must be **testable**. You must be able to design an experiment that supports (or rejects) your hypothesis. The hypothesis should also lead the experiment that is conducted. The experiment will determine if one variable really does affect some other factor.

When you are developing a good hypothesis, you should be able to answer "yes" to the following four questions.

Good Hypothesis Criteria

1. Is there a *condition* that sets up an *effect*?

In other words, what do you think the relationship between the independent and dependent variables is? This is a simple statement that explains what you think the relationship is. Many times it can be written in an "if...then..." format. If this condition occurs, then this effect is produced. Having just the condition and effect is not enough. You have to be able to measure these variables.

2. Does the hypothesis *lead* to an experiment?

Your hypothesis must be something that can be tested. For example, a statement such as "A diety created the universe" is not testable. Can you perform an experiment to test this? No. However, "Plants subjected to classical music while growing will grow taller than plants that are subjected to silence."

3. Is it *clear*?

When you read the hypothesis it needs to be easy to understand. The sentence structure should be mechanically correct and as short as possible saying only what is necessary. Remember that the word **THAN** is a comparison word, the word **THEN** signifies an order in time. (*Example:* First you learn to walk, then you learn to run.)

4. Is it *objective*?

A hypothesis is a formal statement that **does not** use the word "I." It should also be free of personal bias and based on background information and research.

Writing a Statement of Problem or Introduction

Timeline

30–60 minutes

WIC-R Strategies

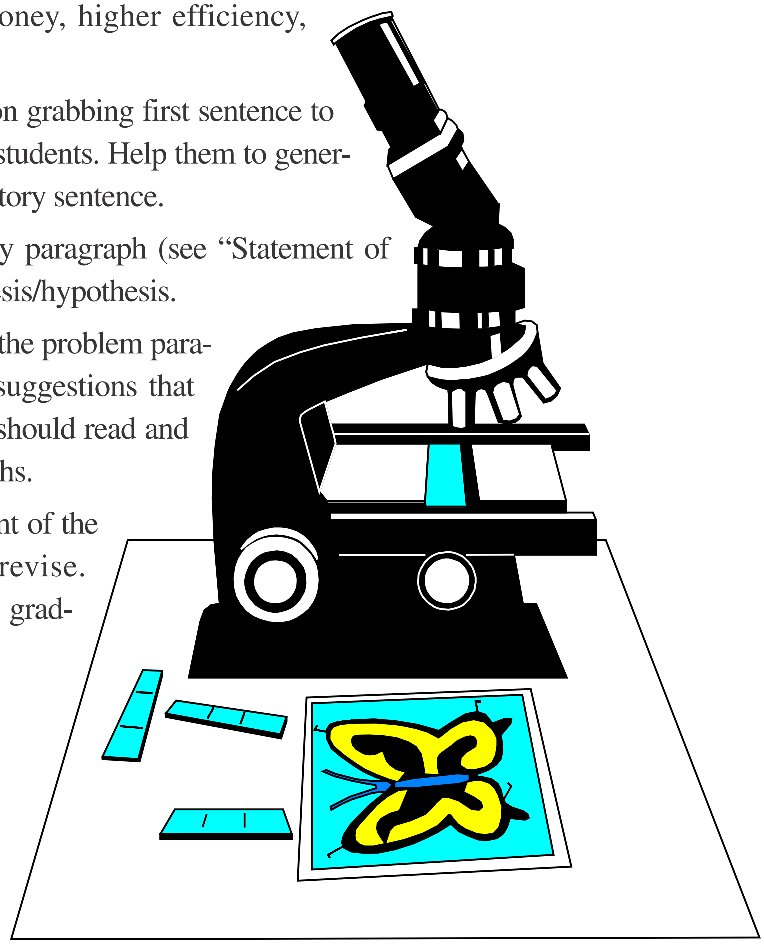
- Writing
- Inquiry
- Collaboration
- Reading

Concept Statement

After students have an approved topic question and hypothesis or thesis, they need to write the introduction for their paper. This is typically referred to as the "statement of problem." A good opening paragraph is interesting to read, motivates the reader to continue reading and provides the framework for the question. When students can write a good introduction, they often become more confident in developing the rest of the project.

Lesson Plan

1. Return approved topics to students.
2. Have students complete a quickwrite (2–3 minutes) about the most captivating ideas about their project. The list might include applications, saving money, higher efficiency, intriguing facts, etc.
3. From this list, have students write an attention grabbing first sentence to open the paragraph. Model this with several students. Help them to generate ideas that would work well as an introductory sentence.
4. Students then complete the first introductory paragraph (see "Statement of Problem"). Then have students write their thesis/hypothesis.
5. Ask students to peer review the statement of the problem paragraphs by exchanging papers and making suggestions that would improve the paragraph. Each student should read and critique at least three other students' paragraphs.
6. Have students revise and submit the statement of the problem to you after taking it home to revise. Review the work and grade according to the grading criteria. Make comments as necessary.



Statement of Problem

The introductory paragraph is called the "Statement of Problem." The purpose is to clarify the reason that this project is important to study and to explain the potential benefits. Use your creative juices to write an opening that is relevant to the topic and entertaining to your audience. Some readers judge whether the paper is worth reading based entirely on the opening sentence. The opening paragraph, therefore, must be interesting to read.

This opening paragraph leads into the main body of the paper. Craft your thoughts so that they lead up to the hypothesis, which serves as the thesis for this paper. The sentences in the statement of problem are linked together using transitions and good writing. The time spent on this paragraph is worthwhile as it sets the tone for the entire paper.

Finally, frame the research question clearly in this paragraph. You are studying a very specific topic. Be sure that the introduction states exactly what you are investigating. You don't want to trick or confuse the reader.

***Avoid the pitfalls* with these helpful hints:**

- No I, we, he, she, you, we, etc. Use formal expository writing.
- The hypothesis is clearly stated. It is underlined. It predicts an answer to the research question. It is worded carefully and precisely.
- The hypothesis was approved previously.
- Check for complete sentences and for correct spelling and usage.
- Proofread your work.

Locating Resources for Research Paper

Timeline

Varies from 45 minutes of library time to 90 minutes (on average depending on the class two 45 minute sessions is ideal)

WIC-R Strategies

- Writing
- Inquiry
- Reading

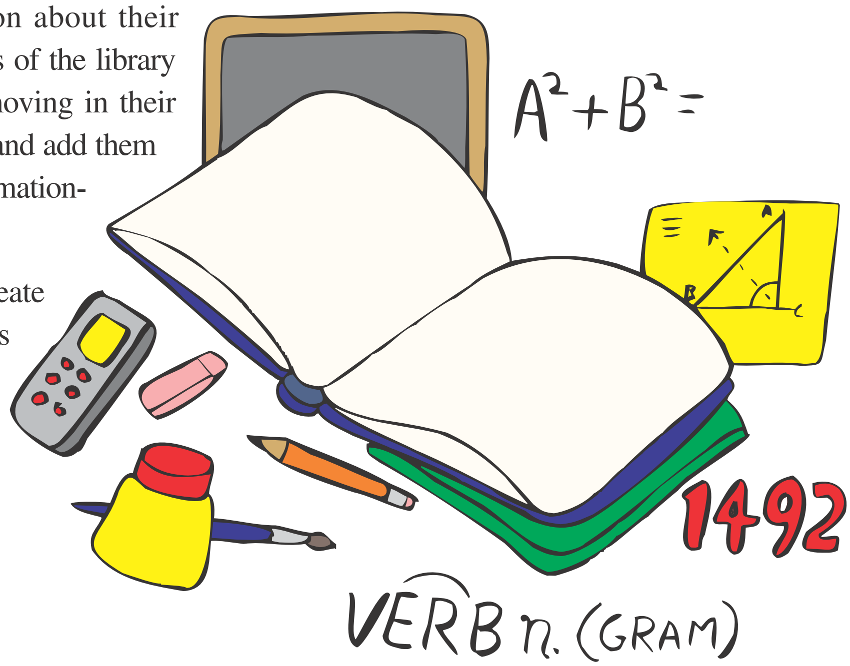
Concept Statement

In order to find good information, students need to consider all possible sources. This includes print media, online journals, a variety of databases, and experts in the field. Many students fail to develop a plan before they start researching so that there is often time wasted on unrelated topics. With a bit of forethought, students can become more efficient researchers and develop better sources of information for their projects.

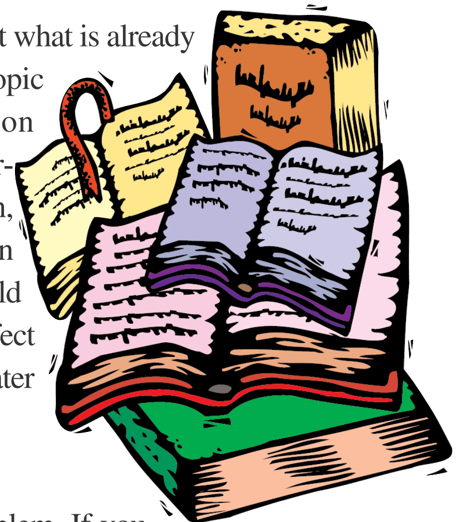
Lesson Plan

Introduce after students have a topic but before they begin to research. This topic should be introdcued at the same time as creating an appendix and evaluating sources.

1. Have students read and complete the student handout "Background Information—Library Research" before they begin to look for sources. Review "Works Cited" handout with students.
2. Take students to the library. Before the trip, work with your librarian to uncover the scientific encyclopedias and other resources in the reference section that students might use to find information about their research question. Introduce the areas of the library to the students to help keep them moving in their search. Have students locate sources and add them to their list on the "Background Information-Library Research" handout.
3. While in the library, have students create the appendix entries for their sources as well as completing the evaluation of their sources.



Background Information—Library Research



In order to make your experiment easier to plan, you will want to find out what is already known about your topic. Sometimes though, just looking up your topic isn't enough. For example, if your project is "Effect of Depth on Underwater Color Photography," you would want to know more about underwater cameras, filters, light refraction, how depth affects color perception, underwater measurements and safety precautions. If you have an interest in oil spills and the effect they have on sea anemones. For this topic you would research waves patterns, ocean currents, conditions and substances that affect the growth of sea anemones, the chemical make-up of oil, how oil and water mix, how to prevent and clean oil spills.

List five or more research topics related to your approved research problem. If you have more than five research questions, write them on a separate piece of paper.

Research Topics

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________

Now get ready to head for the library. For high quality scientific journal sources, your best place is the local college library. The more information that you research, the better your project will be. You are required to have a minimum of FIVE (5) reference sources for your project. Below, list four references that you found at the school library.

School Library References

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________

Works Cited

When you find good information, you want to copy the source and record the "works cited" information. See your teacher for the correct format for a reference list entry. With each tidbit of information that you find, be sure to record the page number and whether it was quoted directly from the source or you paraphrased it.

The information that you need on each source is:

- author's first and last name;
- date of publication (written) or airing (video);
- title of book, magazine, journal, newspaper, etc.;
- title of article;
- page numbers;
- city of publication;
- publishing company's name;
- volume and issue numbers (magazines); and
- web address (required for Internet sources).

High Quality Sources

In order to be sure you are using sophisticated sources, *encyclopedias do not count as sources.* They do provide basic information but it is just that. For better information you need to use books, magazines, journals, etc. Encyclopedias are not just print any more...electronic encyclopedias do not count either.

High quality sources are those sources that provide high caliber, recent information about your topic. They are reports of actual research completed in the field you are studying. Actual research studies are a form of primary sources. Personal interviews, with qualified experts, can also be high quality. However, you must provide the individual's qualifications and other information in the appendix. The authors of these sources publish after a peer review process has occurred. Scientific research is published in acceptable scientific journals. High quality sources have been published recently (within last 10 years). In order to find these high quality sources, you will read many published works that do not fit the criteria and are not used for your literature review. The breadth of the "Work Cited" page will reveal the level of your research effort. The appendix includes many pages that apply to the topic and extensive information from each source that is used in the paper. These sources display minimal bias. High quality sources are carefully selected.

Expert Sources for Personal Interviews

Talk to experts about your topic in the form of personal interviews. Write letters. Find out as much as you can before you start your experiments. List three **EXPERTS** that you could consult about your project:

Possible Experts

1. 2. 3.

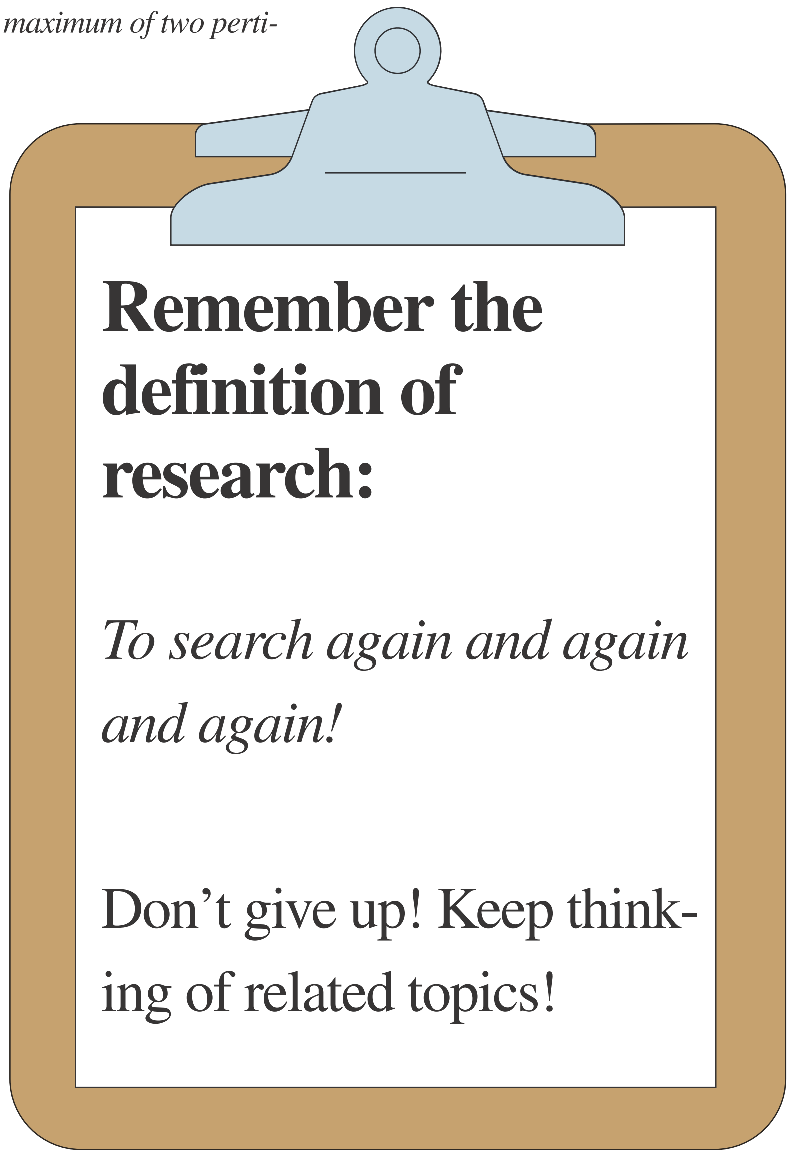
Interviewing Skills

When you consult with an expert you should make sure you have good questions before you conduct an interview. Don't say, "I'd like to do a project on holograms. Where should I start?" Instead ask specific questions that show you have already taken the time to learn something about your topic.

The appendix for a personal interview is a neatly typed list of questions that you used in the interview and a summary of their answers. It includes the name of the expert, date and location of the interview. *The first question always includes a list of achievements, educational degrees, etc. that qualifies the subject as an expert.* An example is what qualifies you as an expert in ____ field?

Reporting About the Background Information

Once you have collected all of the information that you need, you will write your expository paper about the research that has been done in this field. *Be sure to cite all ideas that are not original. It is recommended that you have a maximum of two pertinent cited quotations in this paper.* Citations are made following the idea or quote in the text. At the end of the thought, place the author's last name and page number in parentheses (Molloy, 93). Did you catch that citation?



Evaluating Sources

Timeline

30 minutes for introduction, maximum 20 minutes per source; as students get more proficient each source takes less time

WIC-R Strategies

- Writing
- Inquiry
- Collaboration
- Reading

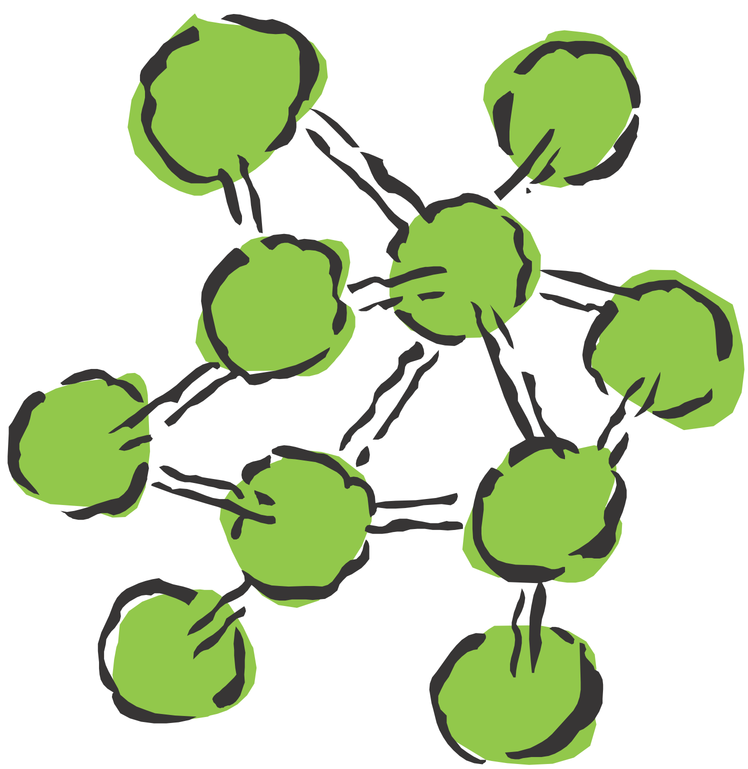
Concept Statement

Not all information is good information, especially when you consider the Internet. Students assume that every site is a good one because it was "published" on the web. Teachers, however, know that this is not true. Students must learn that there are ways to evaluate the credibility and scientific validity of claims. This activity helps students to do just that.

Lesson Plan

Introduce before students begin researching information. This process continues throughout the research process.

1. Have students read the handout "Evaluating the Quality of a Source." Discuss the ideas in the article in terms of trying to evaluate information that is found in resources. Highlight the most important ideas for the project that you are having students complete.
2. Group students in pairs or trios. Have them rate an article or Internet site for source quality and for scientific information based on the rubric provided. Discuss as a class, the reasons for each rating. Have the class come to consensus on the rating.
3. Have students complete "Evaluating the Source."
4. Collect and read. For grading purposes, you can choose to read and comment, check for completion, use peer review strategies or read and grade.



Evaluating the Quality of a Source: Especially Internet Sources

Checklist adapted from *Information Literacy and the Internet,* in Classroom Connect, September 1996.

In order to critically analyze information, a person must consider the source of information, the methods or experimental design used to gather the data, the way in which others review the data and how the data fits with the other knowledge about a topic. This evaluation of information is not unlike determining the veracity of rumors running rampant in the halls of a high school. First, who reported the information? What are their credentials and expertise? Next, how did they gather the information? Was there an investigation? What assumptions were made? Then, how does this information fit with other things you have heard? Is it the same? Are there discrepancies? Finally, are there other reports with the same information? Have others examined the evidence? Did they determine a valid inquiry occurred? Or did an individual merely produce his or her own opinion with little proof?

This checklist provides questions you should consider before using a source of information in a research capacity. Scientists look for sources that are balanced. There is a minimum of bias.

☐ **First** - Always be a little skeptical, very curious, ask questions and examine related information online and offline.

☐ **What is the source of the information?** How can you tell whether you are reading information posted by an organization or by an individual user? A legitimate scientific information provider will have a straightforward online address, such as http://www.xyz.com. An individual user might have an address that looks something like http://www.xyz.com/sjm/data.html.

Print Media: Scientific journal articles depend on a peer review process during which other scientists verify that the authors implemented good science. Journals are usually the highest quality format of true scientific research. Other periodicals like newspapers and magazines tend to report the work of others. It is not a primary document in most cases. A reporter has read all the material and is relating the major points for general knowledge. Be aware that most reporting has an inherent bias about the topic. Use care in which articles you select for a paper.

Books and Video Media: Books are large compilations of scientific work. They may contain original research, but these studies may or may not have been subjected to a peer review process. It is also unlikely that you will use an entire book. Perhaps only a section of chapter will be used. Consider this section as part of the whole when evaluating the source. Informational books need to be current due to the speed with which information is added to our knowledge base. Videos, on the other hand, must be considered in depth. Videos are produced to inform or to persuade. Which was your video trying to accomplish and how does this change the information presented?

☐ **Why is this information presented in this format (online, book, periodical, etc.)?** Evaluate the information. Is the purpose to inform and educate the audience about a topic or is there a hidden agenda? Some sources contain hidden messages that reveal a bias reporting the information. If the site sponsored by a special interest group, the information may only present one side of the issue.

- ☐ **Who wrote the information and what is the point of view of the author?** All credible science sources are authored by people who exhibit an expertise in that field. Some questions that can help you to determine whether someone is considered an expert follow. What else has the author published? Does the author seem knowledgeable about the topic? What types of sources has he/she used to write the source you are evaluating? What are his/her qualifications? Use online search engines and type the name in as a key word. What comes up about the person?

- ☐ **Does the information contain clues that reveal any biases of the author?** Online links to other sites can reveal more about the author. The way a person writes use can also reveal biases. Find out what the person does for a living.

- ☐ **How recent is this information?** All sources for science projects need to have been published within the last 20 years. Sometimes new information is not any more accurate than old information. If you feel that this is the case for a source, consult your science teacher and present your case for using that particular source. Your teacher must approve each source older than 20 years.

- ☐ **How often is the site/information updated?** How recent the information is can provide clues to whether it has been peer reviewed for sound scientific discovery.

- ☐ **How does the information compare with other information that has been written on the same topic?** Search for other information on the topic. Is the source referenced in other works? Does the information seem to be based on the other information that is out there? Reliable information is usually in line with the perspectives of other researchers.

- ☐ **Who is the audience for this information?** For what level is the information intended? Is this the appropriate level for you to cite? Books aimed at children and teenagers should be considered very carefully. They are not usually high quality sources. Online sources that are published by students also need to be considered very carefully. Ask about these sources.

- ☐ **What is the quality of the writing?** Does it follow the basic rules of grammar, spelling and literary composition? Does the author cite information so that you can check for authenticity?

- ☐ **Is there information about contacting the author or producer in the document?** An e-mail address can be valuable in order to get a personal interview via e-mail if the author is credible and the source is high quality.

- ☐ **What is the value of the website?** How does this site compare with the range of resources available in your Library Media Center on your research topic?

Levels of Source Quality

- ☐ **High quality sources** are those sources that provide high caliber, recent information about your topic. They are reports of actual research completed in the field you are studying. Actual research studies are a form of primary sources. Personal interviews with qualified experts are also high quality; however, you must provide the individual's qualifications and a phone number in the appendix. The author's of these sources publish after a peer review process has occurred. The format and location of the information is an acceptable scientific journal. High quality sources have been published recently (within last 10 years). In order to find these high quality sources, you will read many published works that do not fit the criteria and are not used for your literature review. The breadth of the *Works Cited* page will reveal the amount of research effort that you have put in at the library with many sources. The appendix includes many pages that apply to the topic and extensive information from each source is used in the paper. These sources display minimal bias. High quality sources are carefully selected.

- ☐ **Good quality sources** (the mid-level) report on research studies and are known as secondary sources. These sources are of adequate quality. They must be carefully considered before you use them. Included here are newspaper articles, magazine articles from popular science magazines (not journals), and most Internet sources. *Works Cited* pages that reveal many of these types of secondary sources, some primary sources and sources that are published in the last 20 years. The appendix includes many xeroxed pages from each source with much information used from each source showing ample information used for the paper from each source. These sources demonstrate minimal bias in reporting. Good quality sources are carefully selected.

- ☐ **Fair quality sources** are biased in that they do not consider all sides of the topic. They contain more opinion than research and are published in ways that avoid peer review. These sources show poor research skills that will be reflected in the paper itself. Sources are also older than 20 years. A *Works Cited* that is mostly Internet sources or an appendix that is composed of few xeroxed pages from each source demonstrates fair quality sources. This shows limited information used from each source.

- ☐ **Poor quality sources** show little to no effort to seek out good sources. Poor sources display obvious bias, are written for inappropriate audiences and are not published within the last 20 years. Another indicator of poor quality sources is extremely limited information that is used in the paper itself demonstrated by an appendix that includes one xeroxed page for any source.

Evaluating a Source

Reference list entry for source: ____

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What is your overall rating of this source?

☐ High Quality

☐ Good Quality

☐ Fair Quality

☐ Poor Quality

Write a paragraph (6–10 sentences) that explains why you rated as you did. Considered these questions as you prepare to write:

- Who wrote and/or published the information and what is his/her/their expertise?
- What is the author's point of view or bias?
- How this information correlates with other information you know to be true?
- Who previewed this information previous to publishing?

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The Appendix: Keeping a Record of Research

Timeline

Approximately 30 minutes of instruction.

WIC-R Strategies

- Writing
- Inquiry
- Reading

Concept Statement

Students should document their work as they conduct the research. This activity used to be done on index cards. While this is still a good method, often students overlook critical information and then need to return to a particular source of information. Because it is not always feasible to run to the library each time, a photocopy of the source is handy. This documents the entire source. To organize these sources, students create an appendix for their research. They find a source, photocopy or print it out, read it, highlight important information, write the reference list information and then summarize the piece. When students do this it helps them to first understand the article because they had to summarize it and second to make a record to return to later if necessary. From the teacher perspective, this ensures that students really did do the research as well as helps to verify the content of the source information.

Lesson Plan

Introduce before students do research and after they have a topic.

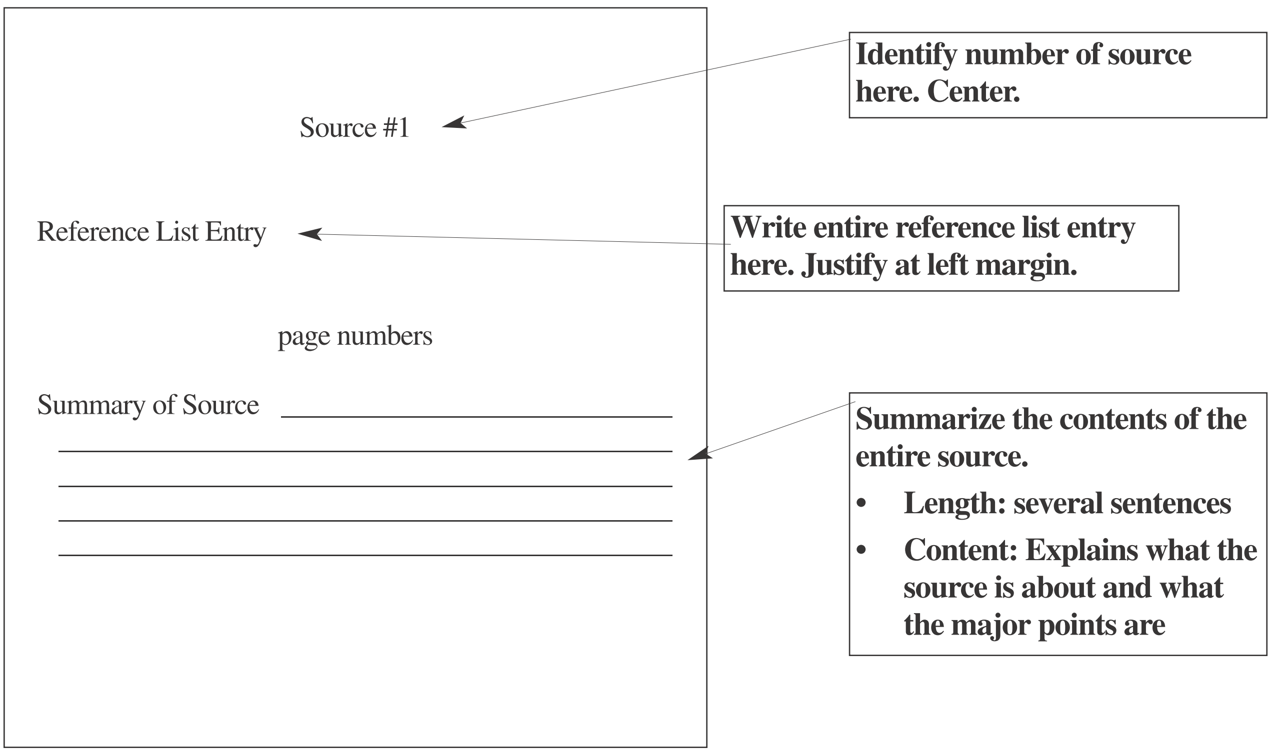
1. Review Student Handouts.
2. Students find a credible source of information. They read the source and then photocopy it.
3. Students highlight the information that they may use in their paper. Students then summarize the entire source.
4. Students write the reference list entry.
5. Students put this together in the format presented on the student handout.
6. You can have students peer review these evaluations, read them yourself and make comments and check for completion or you can read and grade them.

Appendix

The appendix is composed of photocopied or printed copies of **all** sources cited in the paper. Short sources (fewer than 10 pages) will include the entire source photocopied. For books, or other larger sources, you are required to present only the section or sections that you used. Sources that you read but were not used in the paper (and therefore are not cited) or do not count as the five like encyclopedias or CD-ROM information are **NOT** included here.

A cover page precedes each source. The source cover page includes the reference list entry for that source and a summary of the major findings of the source.

Appendix Cover Pages



Photocopied Pages of Source

The pages behind the cover page are neatly 3 hole punched. They appear in numerical order so that the reader can easy follow the source. The information that you used directly, paraphrased AND CITED in your paper is highlighted. All pages you used are included.

Repeat this as necessary. Each source has a cover page and the photocopies.

Sample Appendix Cover Page

Source #2

Keeton, W. T. and Gould, J. L. (1986). *Biological Sciences.* New York: W. W. Norton & Company.

Pages 575–578

Summary:

There are two main strategies evident in bird flight. Wiltscko's experiments on garden warblers show that there is a type of preprogrammed flight in which birds in certain directions for certain periods of time. Other birds rely on a "map or compass sense" in which a bird reacts to the particular area to direct its flight. The experimentation in this type of flight is weak due to the difficulties of actual field research in this category.

The role of the sun and stars is also important to bird flight. Nocturnal birds memorize the constellations and use the stars as reference points. Emlen at Cornell has experimented on this using the North Star as the focal point. Research on homing pigeons demonstrates their use of the sun as a compass. The critical experiment involves changing the hours of light and dark for a pigeon. A pigeon kept in a room whose lights go on and off six hours early—on at midnight and off at noon—will read the sun's position incorrectly based where the bird thinks the sun should be on the rooms daily cycle.

(Following this cover page are the highlighted copies of pages 575, 576, 577 & 578)

Writing the Background Information

Timeline

Dependent on size of project; for five page research paper about 60–120 minutes.

WIC-R Strategies

- Writing
- Inquiry
- Reading

Concept Statement

There are many ways to help students write an actual research paper. Two ways are presented here. The first is a prewriting activity in which students cluster related ideas and begin to construct the organization of their paper. The second is an outline in which students order their ideas more formally and include specific information and citations from their sources.

Lesson Plan

1. Using the concept map on prewriting as a model (see "Background Information on Prewriting"), have students create a cluster or concept map using the information that they highlighted in the appendix. Students should organize information around sub-questions about their topic.

2. Have students write a rough draft of their paper from the concept map.

3. Using the outline: Have students first outline a model paragraph with you to become familiar with the structure. There are many ways to modify an outline so that students are not bogged down by the numbering systems. Sometimes it is sufficient to list ideas for the paper under the paragraph heading and then number them in the order, as they should appear. Then have students outline their statement of problem. As you circulate around the room, check student understanding by reading their paragraphs and outlines to see that the two coincide.

4. Have students list the main topic ideas for their papers in the appropriate part of the outline as designated by the skeleton provided. Students should continue this for all parts of the paper.

5. Collect and read. Comment extensively on the outline with citations. Extra help for students in this phase really pays off on the final paper. Grade according to the rubric "Research Paper Outline Rubric."

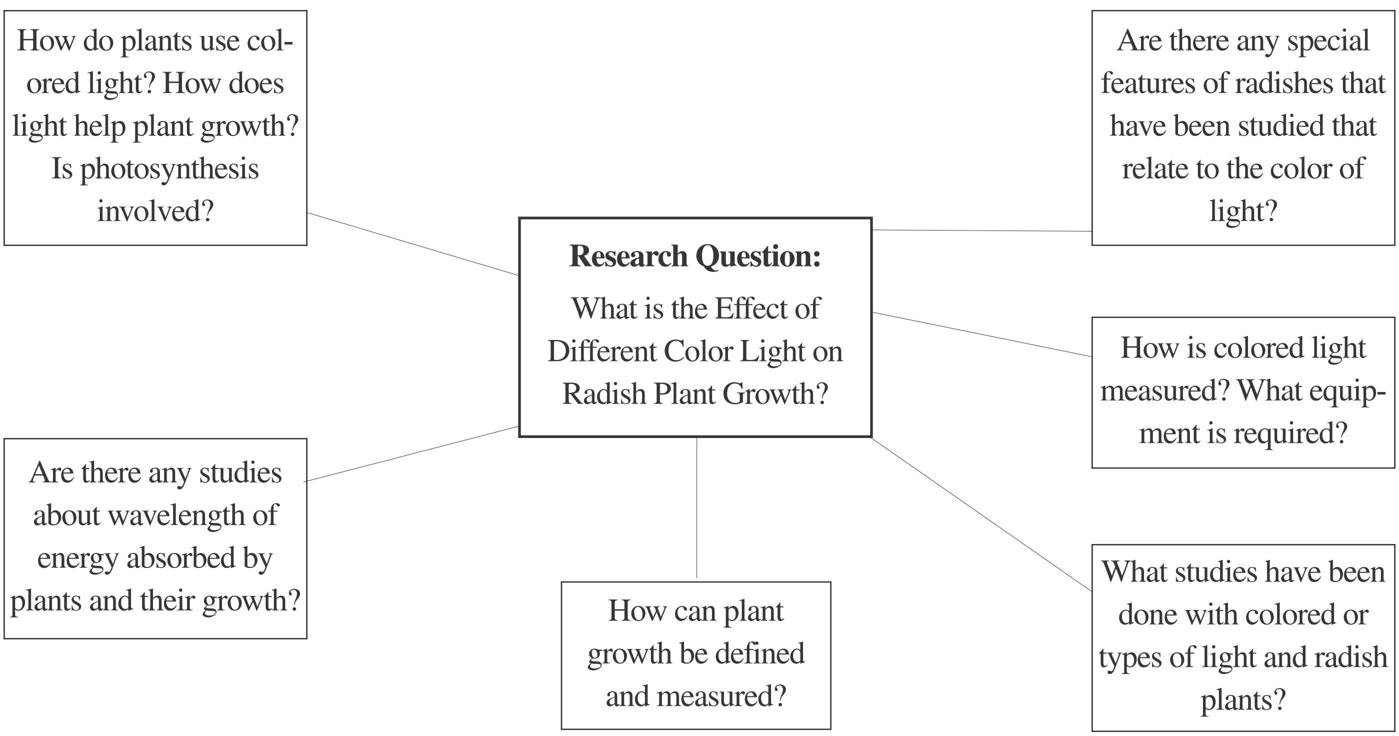
   The advantage of the outline over the map is the power to write the paper directly from the outline because of the linear detail. With maps, students can branch in many directions.

Background Information - Prewriting

Background information provides any and all information that the reader needs to learn to understand the project. All aspects of the research question should be explained in detail. You must define all important vocabulary; explain the concepts that are related to this project and comment of the significance of this information. To do this, you must first organize what you will discuss.

Prewriting

- Gather preliminary research about the topic. Read this information and learn about the concept involved for the lab, Big Project topic or IRP topic. This serves as a starting point.
- Brainstorm the important points of discussion about the topic. Clusters, concept maps or other nonlinear forms of brainstorming work well. Be sure to include questions that will help to design the experiment. As an example, "What are the accepted ways to measure the IV?"



- Now research for information about the questions to which you have not learned the answers. Go back to the library and find more specific information about these concepts. These concepts are very specific and limited to the scope of the project.

Outline

An outline is an organized combination of your notes that defines the structure of your paper. You should use phrases and sentence fragments here. It can always be revised but it must include all major parts of the paper. You should also include the author's name and page number for all information that requires a citation. The following is a template. *You need to fill in the specifics of your paper and add to it where appropriate!*

I. Statement of Problem

- A. Attention-grabber statement
- B. General discussion of topic
- C. Hypothesis (underlined)

Remember that you already wrote this section. Please include the specifics here.

II. Background Information/Review of Literature

- A. Major Idea #1
  1. Supporting Detail
  2. Supporting Detail
  3. Supporting Detail
- B. Major Idea #2
  1. Supporting Detail
  2. Commentary
  3. Supporting Detail
- C. Major Idea #3
  1. Supporting Detail
  2. Supporting Detail
  3. Commentary
- D. Major Idea #4
  1. Supporting Detail
  2. Supporting Detail

The capital letters A, B, C, etc. will be major ideas that will form your paragraphs for the rough draft. Each idea should be kept narrowed to a specific topic that is relevant to understanding your research question and hypothesis. The supporting details and commentary numbers 1, 2, 3, etc. will be included in the paragraph for that particular major idea. You may have as many letters and numbers as required but there must be a minimum of 2 supporting details for each letter.

III. Evidence (Both "for" and "against" your hypothesis) (you need enough entries to be able to write two pages of information).

- A. Evidence #1
  1. Supporting Detail
  2. Supporting Detail
- B. Evidence #2
  1. Supporting Detail
  2. Supporting Detail

Your evidence must provide a balanced view of all evidence that is FOR and AGAINST your hypothesis. You must be objective when weighing the evidence. BE as specific as possible. Follow the same rules for lettering and numbering as on previous page.

IV. Conclusions

- A. Restate hypothesis (remind us)
- B. Major evidence reviewed
- C. Accept or reject hypothesis

V. Where do we go from here?

- A. One possible avenue of research or recommendation
- B. Second possible avenue of research or recommendation

Research Paper Outline Rubric (140 Points)

	Draft	*Revision*	*Final*
Formatting of Outline (20 points)			

- Research question appears above outline
- Proper indentation observed
- Each subtopic is paired (no lone details or minor ideas)
- Parallel structure is observed

Roman Numeral Headings (10 points)			

- Includes basic divisions as Roman numerals
- Each is supported by adequate evidence

Statement of Problem (10 points)			

- Outlined
- Engages reader
- Related to research question
- Hypothesis statement is in sentence form
- Underlined hypothesis

Major Ideas (Paragraph Topic) for Background Information (15 points)			

- Relevant to research question
- Arranged in logical sequence
- Focused on one idea for that paragraph

Supporting Details for Background Information (15 points)			

- Support main topic of paragraph
- Provide information that is vital to reader's understanding of topic
- Includes student commentary about relevance/meaning of information
- Well researched

	Draft	Revision	Final
Major Ideas (Paragraph Topics) for Evidence (15 points)			

- Attempts to answer research question
- Based on scientific research
- Balances the research on the subject rather than presenting biased views

	Draft	Revision	Final
Supporting Details for Evidence (15 points)			

- Strongly relate and support main idea
- Presents scientific research and studies on particular aspect of research question
- Analysis of each piece of evidence including student commentary about how the research supports or rejects hypothesis and what this means to research question (interpretation of research)
- Stated clearly & well researched

	Draft	Revision	Final
Conclusions and Recommendations (10 points)			

- Commentary on predominance of evidence as supporting or rejecting original hypothesis
- States whether overall evidence supports or rejects hypothesis
- Presents other conclusions based on all evidence presented
- Two recommendations on future experimentation that needs completion

	Draft	Revision	Final
Organization/Flow (10 points)			

- Logical organization
- Paragraph topics are focused on one main idea
- Transitions from topic to topic are present

	Draft	Revision	Final
Citations (20 points)			

- Citations are APA style (Author's last name, year)
- Researched material is clearly cited
- Statistics are cited
- Ideas are mainly paraphrased and cited
- Few quotations are used and cited
- No plagiarism - all ideas are presented in student's own words

Documenting Sources of Information

Timeline

30–60 minutes of direct instruction and practice

WIC-R Strategies

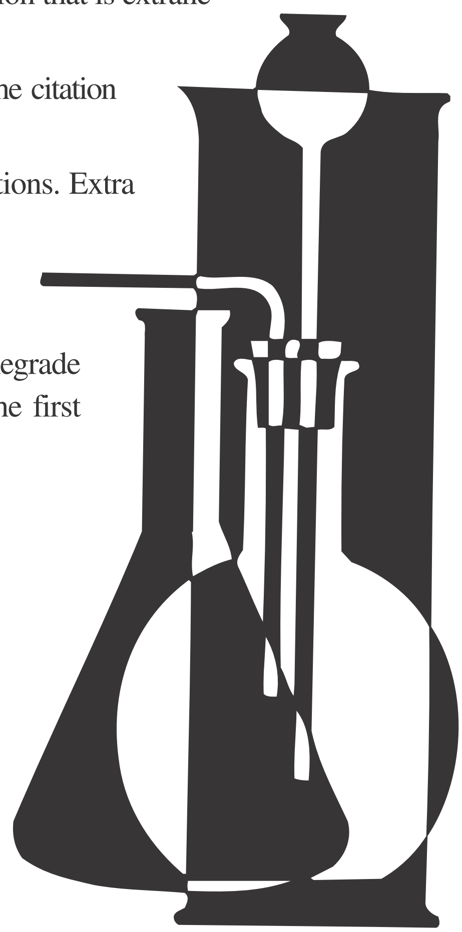
- Writing
- Inquiry
- Collaboration
- Reading

Concept Statement

This activity focuses on how best to cite the source of a piece of information. *Note:* This unit advocates the use of APA style. Other classes may advocates the use of MLA style. In formal science writing, students will need to use APA style. For more information concerning APA Style consult http://www.apastyle.org/. For electronic media (which always seem to be the most difficult), consult http://www.apastyle.org/elecref.html.

Lesson Plan

1. Have students add citations to their outline for any idea that they paraphrased or quoted directly using the appropriate format.
2. Have students review and make sure that almost every paragraph has a citation. If needed, have students find additional evidence or research. Have students look for information that is extraneous and delete from the outline.
3. Have students exchange papers and peer edit the order of ideas, the citation formats and the general flow of the paper.
4. Collect and read. Comment extensively on the outline with citations. Extra help for students in this phase really pays off on the final paper. Grade according to the rubric found with the outline.
5. Return outlines with citations to students for revisions. All students will need to revisit their outlines and provide revisions. Regrade in the second box on the rubric. Return outlines for writing the first draft or more revisions as appropriate.



In-Text Citations Using APA Style

Reading current research is crucial in developing a research paper. You need to acknowledge who did the original research and reference it properly in your research paper.

How many citations are required?

You must have a *minimum of one citation* from each source listed on your reference list page. This is what the term "reference list" means. A rule of thumb is at least two citations per page. The higher the source quality, the more citations you will have.

What needs to be cited?

You must cite:

- direct quotations ... find the original source for the citation;
- statistics, figures, definitions, illustrations or diagrams including xeroxed pictures that you have used to illustrate your paper;
- an original idea or unusually interesting opinion that you have stated in your own words; and
- research methods, data or conclusions that you have stated in your own words after reading about the research or experiment in a journal.

It is impossible for you to cite every idea that you used. You must decide which ideas are *sufficiently original* to require a citation. General information that is common knowledge for someone in this *field* does not require a citation. However, it is best if you have questions about the need to cite an idea you should consult with your teacher.

Direct Quotations

Direct quotations should be used to emphasize your point or to lend support to your conclusions. **Use them sparingly!!!** Long quotations should be single spaced and indented on both sides. Most of your paper will be written in your own words, not quoted.

Types and Formats of APA Style Citations

I. **Narrative Citation:** One type of citation appears as part of your narrative text. A citation that appears this way looks like this:

> Chomsky's (1957) analysis of the process of language acquisition originates with the position that the mind is predisposed to construct and respond to language in certain ways.

The idea is their original idea and the year indicates the recency of the information. The advantage of this type of citation is that you can use the active voice and you qualify the expertise of the author with their name.

II. **Parenthetical Citation:** The conventional approach to citations is to write the author's name, year in parentheses at the end of the cited idea. For example:

> Certain results raise the suspicion that members of peer review boards may harbor different biases regarding the costs and benefits of the studies they are asked to evaluate (Ceci, Peters & Plotkin, 1985; Hamsher & Reznikoff, 1967; Kallgren & Kenrick, 1990; Schlenker & Forsyth, 1977).

This particular idea was referenced in four different articles. These articles are listed in alphabetical order by first author's last name.

III. **Cases of more than two authors:** In the case that there are more than two authors, you state only the last name of the first author listed followed by et al. This applies for both narrative and parenthetical citations. For example:

> The polymerase chain reaction (PCR) is a method of in vitro cloning that can generate large quantities of a specific DNA fragment from a small amount of different genes (Saiki et al., 1985).

IV. **Two works published by the same author in the same year:** The proper sequence of these citations is by listing the last name of the author and then the year followed by the lowercase letters a, b, c, etc. as needed. The "a" reference is the first listed for that author on the Reference list page. For example:

> (Molloy, 1993a, 1993b, 1993c) where 1993a is the first listing for these references for Molloy on the Reference list page.

Works Cited/Reference List Page in APA Style

Timeline

30 minutes of instruction; 30 minutes to format and create

WIC-R Strategies

- Writing
- Inquiry
- Collaboration

Concept Statement

Pulling together the reference list page is often the easiest part of the research paper. Having completed the research, students need to format the information in an alphabetical listing of the sources. This activity by no means provides solutions for every example, but rather focuses on the basic challenges that pre-college students often encounter.

Lesson Plan

1. Have students use the following websites dedicated to APA Style to format the entries for their Work Cited/Reference List of materials that are cited in their paper. Below are examples of good websites that cover this topic. If the links are no longer valid, complete an Internet search for "Works Cited APA Style."
2. Have students peer review the work and revise. Have students revise for the final draft. Collect and grade for correctly writing each entry.

Online APA Resources for Students

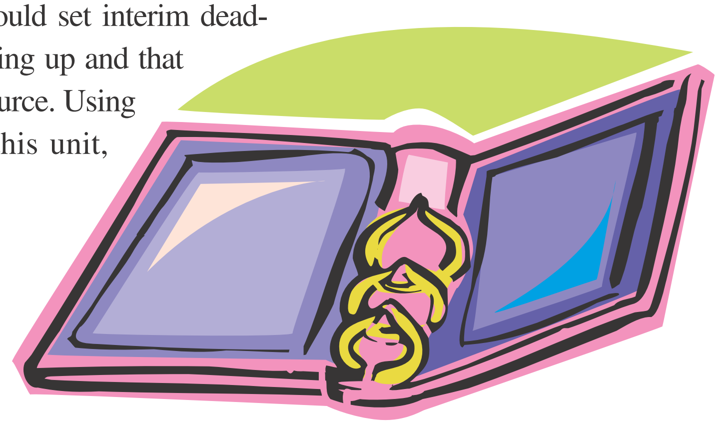
http://www.lib.duke.edu/libguide/works_cited

http://www.millikin.edu/wcenter/apa1.html

http://writing.colostate.edu/demos/apa_reference/

http://www.ucalgary.ca/UofC/eduweb/grammar/guide/apastyle.htm

Putting together all the steps in this unit can result in a final research paper. The rubric provided should be given to students before the project starts. You should set interim deadlines for the paper to ensure that students are keeping up and that the work is that of the student and not an outside source. Using the specific lessons and activities provided in this unit, should result in better products.



Research Paper Rubric Final Draft (230 Points)

COVER PAGE ***REQUIRED OR -5***

Statement of the Problem **(10 points maximum)**

- Includes underlined hypothesis, interesting and engaging *(+10)*
- Includes underlined hypothesis, somewhat interesting and engaging, *(+8)*
- Lacks underlined hypothesis, relevant but uninteresting/not engaging *(+6)*
- Lacks underlined hypothesis, short of appropriate length, irrelevant *(+4)*

Background Information **(40 points maximum)**

- Presents research strongly related to the question, displays discretion between relevant information and trivial facts, well researched and interesting (+40)
- Presents research sufficiently relevant to the question, displays some discretion between relevant information and trivial facts, adequately researched and somewhat interesting *(+35)*
- Presents research weakly relevant to the question, displays some discretion between relevant information and trivial facts, adequately researched *(+25)*
- Presents research irrelevant to the question, displays little discretion between relevant information and trivial facts, poorly researched *(+10)*

Presentation of Evidence **(40 points maximum)**

- Presents balanced survey of current research to support and reject hypothesis, all commentary evaluates the validity of the research and why it is good or bad research, all research is relevant and organized, well researched *(+40)*
- Presents somewhat balanced survey of current research to support and reject hypothesis, some commentary evaluates the validity of the research and why it is good or bad research, some research is relevant and organized, adequately researched *(+35)*
- Presents poorly balanced survey of current research to support and reject hypothesis, little commentary evaluates the validity of the research and why it is good or bad research, all research is relevant and organized, minimally researched *(+20)*
- Presents little to no evidence and/or little to no commentary, poorly researched *(+10)*

Conclusion **(20 points maximum)**

- Clearly states acceptance/rejection of hypothesis; clearly explains why hypothesis is accepted or rejected; conclusions solidly based on researched evidence, commentary leads up to conclusions, clearly communicated (+20)
- Clearly states acceptance/rejection of hypothesis; adequately explains why hypothesis is accepted or rejected; conclusions solidly based on researched evidence, commentary somewhat leads up to conclusions, communicated adequately, gaps in reasoning *(+15)*
- Whether hypothesis accepted/rejected is unclear; somewhat explains why hypothesis is accepted or rejected; conclusions weakly based on researched evidence, commentary does not lead up to conclusions, poorly communicated, lacks reasoning for conclusion *(+10)*
- No conclusions *(+0)*

Where do we go from here? **(10 points maximum)**

- Presents a realistic research avenue from the ideas in this paper, presents new hypothesis tightly related to this topic to test *(+10)*
- Presents a plausible research avenue from the ideas in this paper, presents new hypothesis somewhat related to this topic to test *(+8)*
- Presents a poor research avenue from the ideas in this paper, presents new hypothesis hardly related to this topic to test *(+6)*
- Research avenue is not research oriented in nature, hypothesis is not presented *(+4)*

Citations **(20 points maximum)**

- Always uses proper APA format, always represent the ideas or words of others, always used appropriately, demonstrates balanced number of citations from each source *(+20)*
- Often uses proper APA format, mostly represent the ideas or words of others, often used appropriately, somewhat demonstrates balanced number of citations from each source *(+16)*
- Occasionally uses proper APA format, occasionally/randomly represent the ideas or words of others, occasionally used appropriately or random usage, poorly balanced number of citations from each source *(+14)*
- Rarely/randomly uses proper APA format, rarely represent the ideas or words of others, rarely used appropriately, does not balanced number of citations from each source *(+10)*

Works Cited **(20 points maximum)**

- APA style, five high-quality and varied sources, current research included *(each source is worth 2 points)*

Appendix **(50 points maximum)**

- Has six sources, with cover page correctly formatted.
- Includes photocopy or printout of source materials.

Quality of Sources (minimum of five sources) **(20 points maximum)**

- High quality scientific sources: published within last 10 years, mostly primary sources, shows different types of sources, all sources are credible and authored at appropriate level, each source provides extensive information used in paper, demonstrates exceptional research effort *(+20)*
- Good quality scientific sources: published within last 20 years, shows some different types of sources, most sources are credible and authored at appropriate level, each source provides ample information used in paper, demonstrates satisfactory research effort *(+15)*
- Fair quality scientific sources: published within last 20 years, shows mostly same types of sources, most sources are biased, audience below acceptable level, source provides limited information, demonstrates fair research effort *(+10)*
- Poor quality sources: most sources written for inappropriate audience, not recent, display obvious bias, source provides extremely limited information, poor research effort *(+5)*

Research Question and Statement of Problem Paragraph **Required or -10**

Outline & Rough Draft **Required or -10**

Showcase Project

Timeline

6–8 weeks

WIC-R Strategies

- Writing
- Inquiry
- Collaboration
- Reading

Concept Statement

The day-to-day operation of AP classrooms focuses on the smaller research type material like lab reports. Students are rarely given the opportunity to stretch their learning outside of the classroom to other science ideas. This project encourages students to think about their discipline outside the curriculum. They must research a current issue in which they are interested and then create a poster to inform others about the topic. This exercises their reading, writing and thinking skills in presenting information to others who may not have the same expertise as they do. This project not only benefits the students in the course but also the student body by increasing awareness of the current science issues.

Lesson Plan

While a stand-alone project that runs concurrent to the course, it is important to begin this project at the start of the course. This gives students time to select a topic and produced preliminary research before the content material becomes too staggering. Starting early promotes richer discussions when students bring in the applications they have learned through the project to the class discussions. Additionally, in the AP world, teachers need to avoid having large projects due near AP testing time for obvious reasons.

1. Have the class team up in groups of two or three. Students need to work well together and have similar times outside of class to meet together to prepare the project.

2. Use a calendar to prepare the display dates that are available. Have students select their due dates based on the time period in which they want to display their poster. With AP students, this is quite easy. Most groups know when they have the heaviest workloads and will plan appropriately for this project in order to get it done on time.

3. Have students decide on the topic within a week of presenting the project. You need to set the parameters. For the project presented here, students were limited to the theme of “Chemistry in Everyday Life” with the intention that they are to increase chemistry awareness to the school population. The advantage of changing the theme every year is that students cannot rely on last year’s projects for an easy project. The topic must be unique in the set of students. Students sign up their preliminary ideas on a first-come-first-served basis. The first group to pen their ideas has priority. For a topic to be accepted it must be directly related to the discipline;

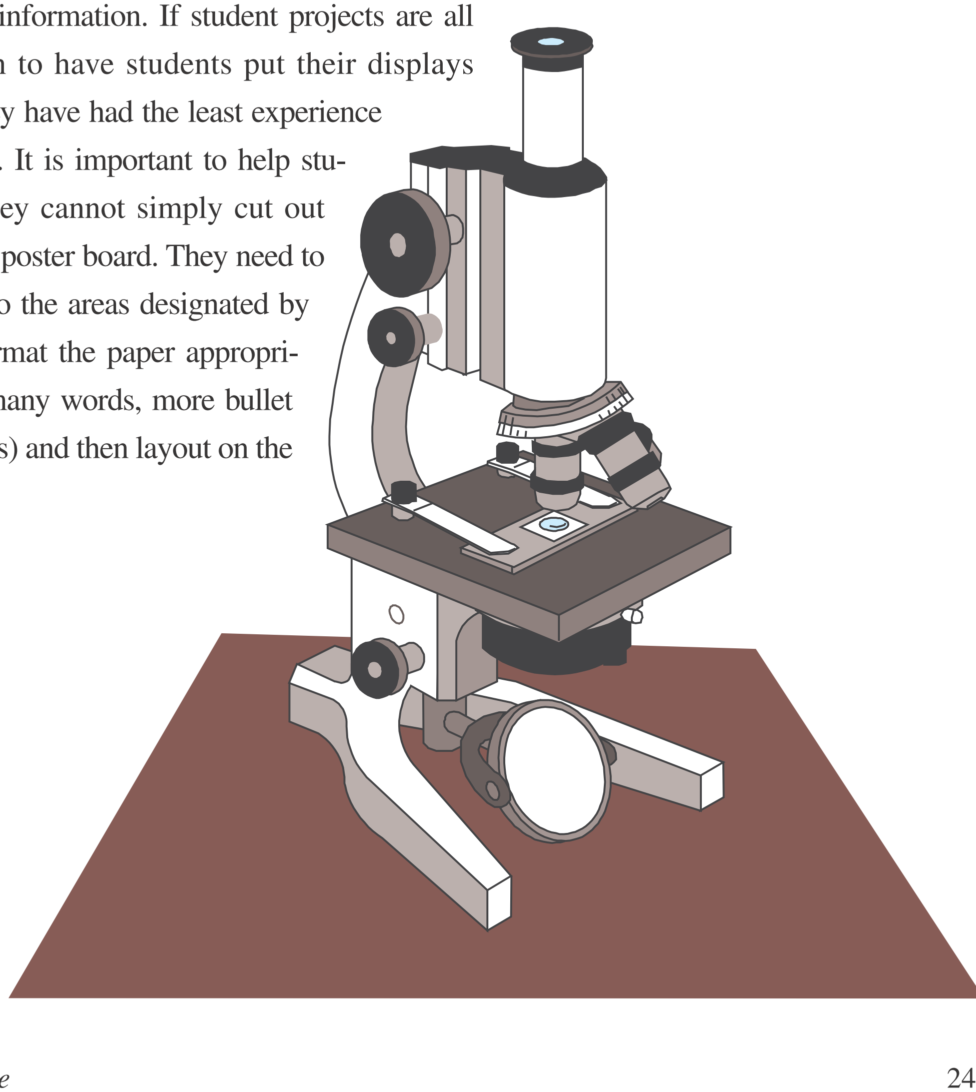
be unique; be broad enough for research based on the available resources; and be narrow enough in focus to be presented in the paper and the display poster.

4. Students then need to write a 1–2 page rationale for the importance of the project within two weeks of presenting the project. This is the **Topic Proposal.** Students must write a persuasive argument that stimulates interest in the project. The purpose is to relate why this is an important area of study as well as to pique the audience's interest in reading more. This needs to include research (all cited appropriately) to support the claims in the proposal. [Note this part of the project needs to keep rolling in order for students to start their research so that fewer topic changes will need to be made.]

5. You now read the proposals, edit and propose revisions. Return the proposals and have students revise within one week.

6. Next, students need to write the research paper. How much instruction you provide depends on the past experience of your students.

7. After students read the research project, they need to design their poster. The easiest type of display is the three-part science fair display boards purchased at craft stores. Limiting the size of the display helps students to present the most important information. If student projects are all due at the same time, plan to have students put their displays together in class because they have had the least experience with visual display of work. It is important to help students to understand that they cannot simply cut out their paper and glue it to the poster board. They need to divide the original paper into the areas designated by the rubric, rewrite and reformat the paper appropriately for a display (not so many words, more bullet ideas, more charts and graphs) and then layout on the poster before attaching.



Showcase Project Rubric (230 Points)

Topic Proposal **(10 points maximum)**

- Unique topic, generates scientific interesting or global questions, complex/AP level, well-researched, approved *(+10)*
- Unique topic, intermediate level, generates scientific questions, complex, researched, approved *(+8)*
- Basic level of science, generates scientific questions, minimal research, approved *(+6)*
- Related to subject, minimal research, approved *(+4)*
- Vaguely related to subject, appropriate for high school audience, approved *(+2)*

Research Paper (5–7 pages) **(80 points maximum)**

- Strong introduction, clear point of view or focus, presents recent research strongly related to topic, demonstrates discretion between relevant information and trivial facts, presents balanced survey of current research, integrally related to topic, all commentary evaluates the validity of the research (pros and cons), all research is relevant and organized, well-researched, interesting to read, balances citations (+80)
- Presents research sufficiently relevant to the question, displays some discretion between relevant information and trivial facts, presents somewhat balanced survey of current research, some commentary evaluates the validity of the research, some research is relevant and organized, adequately researched somewhat interesting, balances citations *(+70)*
- Presents research weakly relevant to the question, displays some discretion between relevant information and trivial facts, presents poorly balanced survey of current research, little commentary evaluates the validity of the research, minimal research is relevant and organized, minimally researched, relies heavily on few sources *(+50)*
- Presents research irrelevant to the question, displays little discretion between relevant information and trivial facts, presents little to no information about topic and/or little to no commentary, poorly researched, unbalanced citations *(+20)*

Display: Introduction **(10 points maximum)**

- Concise paragraph, includes appropriate attention grabber, piques interest, states clear point of view or focus to research, clearly conveys importance or applications of this topic *(+10)*
- Paragraph includes attention grabber, attempts to pique interest, point of view or focus to research is evident although uncertain, adequately conveys importance or applications of this topic *(+8)*
- Point of view or focus to research is unclear/vague, hints at importance or applications of this topic, roundabout writing *(+5)*
- What introduction? *(+0)*

Display: Presentation of Research **(50 points maximum)**

- Concise well-written paragraphs, ideas relate to topic, and clearly explained, uses appropriate vocabulary, relates to concrete ideas, graphics support learning *(+50)*
- Has paragraphs, explains topic ideas, high school reading level, most ideas relate to topic, adequate scientific explanations, sometimes uses appropriate vocabulary, relates to concrete ideas, graphics support learning *(+40)*

- Has paragraphs, topic ideas unclear, reading level is too high/low, some ideas relate to topic, scientific explanations make reader think its magic, infrequent use of science vocabulary, ideas are consistently abstract *(+30)*
- Has paragraphs, reading level is too high/low, unclear how ideas relate to topic, lacks scientific explanations, rarely uses appropriate vocabulary, too abstract *(+20)*

Display: Conclusion **(20 points maximum)**

- Draws clear conclusions about topic based on researched evidence, conclusions based on commentary, well-written *(+20)*
- Draws conclusions based on researched evidence, conclusions based loosely on researched evidence, gaps in reasoning, adequate writing *(+15)*
- Unclear conclusions weakly based on researched evidence, commentary does not lead up to conclusions, lacks reasoning for conclusions, poorly written *(+10)*
- Vague, unclear conclusions, minimal or basis on research, *(+5)*

Display: Further Research **(10 points maximum)**

- Suggests 4 accessible sources for more information on topic, types of sources are varied *(+10)*
- Suggests 3 accessible sources for more information on topic, types of sources are varied *(+8)*
- Suggests 2 accessible sources for more information on topic, types of sources are varied *(+6)*
- Suggests 1 accessible sources for more information on topic, types of sources are varied *(+4)*

Display: Appearance **(20 points maximum)**

- Creative title, layout is easy to follow, uses color to accentuate content, neat and aesthetically pleasing, eye-catching, fonts are legible and sized appropriately, high quality color graphics/pictures integral to topic, support display, citations as appropriate *(+20)*
- Clear title, layout is moderately easy to follow, uses color throughout, neat and aesthetically pleasing, fonts sizes too small/too large, difficult to read due to font, moderate quality color graphics/pictures related to topic, unclear their intent, citations as appropriate *(+16)*
- Has title, layout impedes flow of ideas, uses color, fonts and font sizes impede reader, poor quality graphics/pictures unrelated to topic, few citations *(+10)*

Works Cited **(10 points maximum)**

- APA style, 5 high-quality and varied sources, current research included *(each source is worth 2 points)*

Quality of Sources (minimum of 5 sources) **(20 points maximum)**

- High quality scientific sources: published within last 10 years, mostly primary sources, shows different types of sources, all sources are credible and authored at appropriate level, each source provides extensive information used in paper, demonstrates exceptional research effort *(+20)*
- Good quality scientific sources: published within last 15 years, shows some different types of sources, most sources are credible and authored at appropriate level, each source provides ample information used in paper, demonstrates satisfactory research effort *(+15)*
- Fair quality scientific sources: published within last 20 years, shows mostly same types of sources, most sources are biased, audience below acceptable level, source provides limited information, demonstrates fair research effort *(+10)*
- Poor quality sources: most sources written for inappropriate audience, not recent, displays obvious bias, source provides extremely limited information, poor research effort *(+5)*

Evidence for the Big Bang

Timeline

Three 90-minute classes

WIC-R Strategies

- Writing
- Inquiry
- Collaboration
- Reading

Concept Statement

Evidence of the Big Bang is an example of how to integrate many of the strategies from this publication into a single lesson. The purpose of this lesson is to engage students in the learning process by having them research lines of evidence that support a scientific theory, The Big Bang. While the Big Bang is not an obvious choice for a chemistry class, this event does define the beginning of the universe and opens a dialogue for students about energy and matter, the heart of chemistry and all science. Through this lesson, students are introduced to the ideas of scientific theories and laws. They begin to seriously evaluate evidence that supports or refutes a theory in order to become better critical thinkers about scientific ideas. Additionally, these students begin to ask questions about the stuff the universe is made of as well as why events happen as they do. There are three main parts to this lesson.

1. What evidence supports the Big Bang Theory?

At one time, prevailing scientific thought put forth that the universe had no beginning and no end and it would perpetually look the same everywhere. However, in 1929, Hubble discovered that the universe was indeed expanding, casting serious doubt on the so-called Steady-State Theory of the universe. In 1948, Gamow and Alpher proposed that the universe began with a burst of nuclear fusion that created all the elements, the Big Bang Theory.

Over time, this theory has developed to account for several lines of scientific data. These lines of data include: an expanding universe; the existence of quasars at far distances indicating that the universe has indeed changed with the passage of time; the theory of special relativity requirements that as you move closer to light speed, mass increases, time slows and length increases; and cosmic microwave background radiation levels that persist from the instant of formation from the cooling of the universe after the initial heat.

2. What is a scientific theory? How does a theory differ from a scientific law?

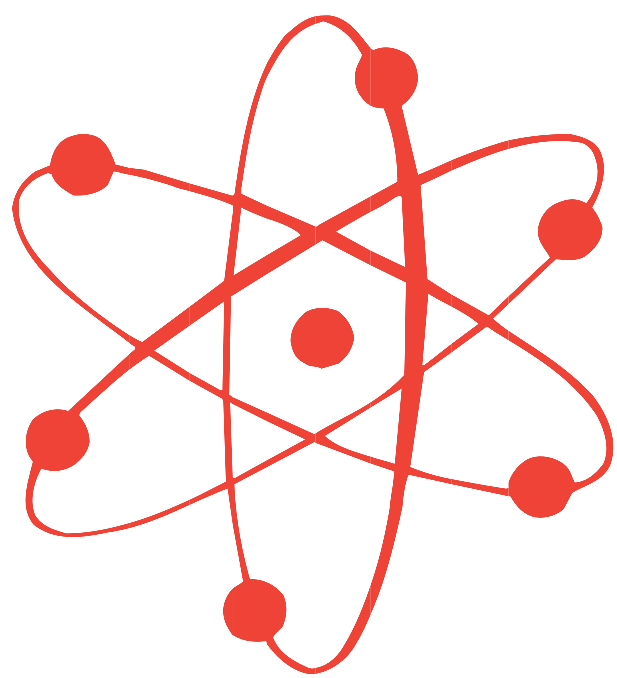
A scientific theory or model is an explanation of some natural phenomenon. An interpretation of information, a theory is based on sets of hypotheses that agree with various observations. Theories are based on recordable, measurable events. Theories change over time as new information becomes available from new experimentation. Scientists continually refine and retest theories by asking more questions about behavior. Scientific theories are based on evidence, not beliefs. There are facts and observable events that support a theory.

A scientific law, on the other hand, is a summary of observed behavior. As scientists observe nature, they see that the same observation applies over many systems. There is no attempt to explain the reason for the behavior, merely a summary of the observations.

But remember that scientists can bring very human prejudices to their observations. They can misinterpret data. They have political leanings or other biases. They have emotional attachments to their ideas that can result in a loss of objectivity. They have religious beliefs that may result in them overlooking observations to fit their belief system. Scientists are affected by the times in which they live as well.

3. How does a person evaluate the credibility and significance of scientific information?

In order to critically analyze information, a person must consider the source of the information, the methods or experimental design used to gather the data, the way in which others review the data and how the data fits with the other knowledge about a topic. This evaluation of scientific information is not unlike determining the veracity of rumors running rampant in the halls of a high school. First, who reported the information? What are their credentials and expertise? Next, how did they gather the information? Was there an investigation? What assumptions were made? Then, how does this information fit with other things you have heard? Is it the same? Are there discrepancies? Finally, are there other reports with the same information? Have others examined the evidence? Did they determine a valid inquiry occurred? Or did an individual merely produce his or her own opinion with little proof?



Lesson Plan

Day 1: Discussion of Scientific Theories and Laws

- Start KWL chart (Know, Want to Know, Learned): What is the Big Bang?

Know	Want to Know	Learned

  In groups of 3–4 students will generate a list of all the things they "know" about the Big Bang in the first column (K) of a three-column chart. After four minutes, each group will report out one idea to place on the class chart. This will continue until all ideas are placed on the class KWL chart. Next each small group will add three things they want to learn about the Big Bang on the second column of their chart. We repeat the report out procedure for the class. Collect group KWL's and post class KWL on wall for duration of the lesson.
- Present idea that Big Bang is a scientific theory, an interpretation of observable events to explain a natural phenomenon. Define scientific theory and have students generate a list of known scientific theories by name and/or description. Give students the name or concise description when they have difficulty articulating. When a scientific law is mentioned, discuss meaning of scientific laws as summary of observations. Use pair-share strategy for students to write about theories and laws in their own words and then share their ideas with a partner.
- Have students use computers to find one example of a scientific theory and one example of a scientific law. They must name the theory/law and describe it. Share out to the class various ideas that the class researched. Explain why each is a theory or law.
- Have students individually complete "Theories and Models and Laws, Oh My!" to classify various chemical principles as theories/models or laws. Have students work together in pairs to review their answers and make changes as they see necessary. Collect.
- Assign Homefun: *See* Student Handout "The Big Bang Model of the Origin of the Universe" for direction.

Day 2: Theory of Big Bang: The Search for Scientific Evidence

- check discussion log (homefun) for completeness.
- Review idea of theory/model v. law with yesterday's classwork: Theories and Models and Laws, Oh My! Students should make the appropriate changes to their work with a different color ink. Name scientific principles at this time.
- Have students explain how they determine whether a rumor going around school is true or not. Students first jot down their ideas for how they would figure this out. Then share as a class generating a list of ideas to determine the veracity of the rumor. Next explain that scientists also have a similar process of evaluating information from a source. The key steps include considering: the source of information, the methods or experimental design used to gather the data, the way in which others review the data and how the data fits with the other knowledge about a topic. [Note: The methods students use to uncover the truth behind rumors will vary. Discuss and accept ideas on case-by-case basis.]
- Have the class evaluate the source used for homefun: Use the handout "Evaluate A Source" found in this unit. Discuss how we know this is a credible source: the authors, the corroboration with other major scientists, peer review processes in editing, etc. Discuss how the internet makes this process more difficult due to ease of posting information, the hidden bias of authors, the credentials of the author are not always readily apparent, the level of information presented may obfuscate the legitimacy for the layperson, etc.
- Lead a class discussion that illustrates the major evidence of the Big Bang from their reading already. The major lines for discussion include:
  a. Hubble's discovery that the universe is expanding and the evidence produced by gravitational lenses;
  b. quasar existence and variant density in the universe indicating that the universe changes over time, that

   the universe is aging;
   c. special relativity indications as you close in on the speed of light: mass increases, time dilation, changes in length;
   d. the conditions at Big Bang would result in the relative amounts of hydrogen and helium as supported by particle accelerator experiments; and
   e. the cooling of the universe as evidence by cosmic microwave background radiation.
- Have students work in groups of 3–4 to more fully develop three lines of valid, scientific evidence for the Big Bang. They many choose from the ideas above or seek out new lines. They may use periodicals, Internet sites, books and other materials with teacher permission. Each student must have three lines of evidence from three different sources (two required, one found on their own) with details to support their understanding and the significance of these ideas by mid-class tomorrow.
- Have students critique each of their three sources as they read and use the material. There should be one completed "Evaluating a Source" worksheet for each source. Students should write their evaluation independent of their group although they should discuss the merits of the science and the authenticity of the source with their peers.

Day 3: Discussion of Evidence and Assessment
- *Visual Demonstrations and Computer Simulations:* Present students with some/all of the following illustrations to help students visualize these complex ideas more concretely.
   1. Balloon with Galaxy dots, the galaxies are moving farther apart as balloon expands
   2. Doppler effect using sound: Tie a tuning fork onto a string and swing it around my head and move around the room. Kids will hear the changing pitch. Using LCD projector, demonstrate Doppler effect for sound using website http://library.thinkquest.org/19537/java/Doppler.html Explain how a moving object changes the frequency of the waves emanated and therefore the pitch of the sound we hear. Relate this to frequency and wavelength of light waves for moving objects to demonstrate the red shift, part of the evidence supporting Big Bang. Discuss transparency from Challenge Foundation that demonstrates how all parts of the universe feel like they are the center of Hubble's expansion. (I don't have a copy of this transparency on hand right now as I am on leave from school.)
   3. Light clocks to demonstrate time dilation when moving closer to the speed of light.
   4. Use graph (found in website below) of COBE data for cosmic background radiation and temperature of the universe to demonstrate that observation and theoretical ideas match up http://www.damtp.cam.ac.uk/user/gr/public/cmbr_temp.html.
- Students continue their search for evidence in small groups.
- Halfway through the period, the class reconvenes. Each student chooses one line of evidence to present as the expert. Students then regroup based on their expert topic in a cooperative learning strategy. Each Expert group creates a poster to share that defines the evidence and explains it. After 30 minutes, groups rotate to different posters and add to their individual notes about each line of evidence.
- Complete KWL chart: What is Big Bang from Day 1. Return group KWL charts. In same small groups, students list what they have learned from the lesson in the third column of the chart. Report out to class as previously.
- Homefun: Students write a three-paragraph essay that presents thee evidence for the Big Bang theory as the creation of the universe based on the information presented by themselves and their peers.

Day 4 & 5: Assessment
- Peer review essays. Look for grammar issues as well as clarity of thought. Students should make comments that help students with their expression of ideas in order to reach a higher level on the rubric.
- Students discuss comments with each other.
- Students revise essays for submission next class.

Assessment of Students

- *Critique of Scientific Evidence:* Students will complete a critique sheet for three sources of information (2 required from list, 1 found by student) concerning evidence for the Big Bang Theory. Students will be evaluated on the level of source material as well as their analysis of the scientific validity of the claims based on the scientific experimental design, the peer review process and corroboration with other observable evidence.
- *Three-Part (Five-paragraph) essay:* Students will present their understanding of the Big Bang theory and supporting scientific evidence by writing a five-paragraph essay. The first paragraph is the introduction. Students begin with a discussion of what a scientific theory is and conclude with the hypothesis that the Big Bang is indeed the way scientists actually know the universe was created. Each of the next three paragraphs explains one major piece of evidence that supports the theory. Each paragraph will need to cite sources of information as well as evaluate the significance and validity of the ideas. The conclusion paragraph will recap the evidence and spells out why the Big Bang is a theory and not a belief system.
- *Participation in class discussion:* Observation of student knowledge through contributions in class discussions throughout the three-day unit. Assess level of student participation with factual information, application levels of material and analysis of information based on what students say during KWL discussions, as they collect sources and during the demonstrations. Nonverbal participation through body language will be considered as well. Are students mentally engaged by looking at the speakers, jotting down notes, sitting up in their seats, nodding or shaking their heads in agreement, etc.? Students who have learned at a deep level and are interested will appear to be involved in the discussion even when they are not speaking at the moment.

Overhead Transparency/Student Handout

KWL Worksheet

K What Do I Know?	W What Do I Want to Know?	L What Did I Learn?

Theories and Models and Laws, Oh My!

In your own words, define the following as scientific concepts:

Theory ____

____

____

Law ____

____

____

Classify each of the following scientific ideas as a theory or a law. Give a one-sentence explanation as to your classification. After the class discussion, write the scientific name of each idea.

Name of Scientific Principle	Theory or Law?	Description of Scientific Principle
		Change occurs over time in populations through mutation to develop new species
		The total mass of reactants of a chemical reaction will equal the total amount of products of the reaction
		Gases are composed of small particles in constant, straight-line motion that experience elastic collisions when they collide and are neither attracted nor repelled by each other
		A given compound always contains exactly the same proportion of elements by mass
		The energy of the universe is constant
		Molecular shape can be predicted based on the number of bonding and nonbonding pairs of electrons of the central atom of a molecule
		Describes the behavior of electrons as wavelike and describes the probable location of them around the nucleus

Theories and Models and Laws, Oh My!

In your own words, define the following as scientific concepts:

Theory: an explanation of scientific phenomenon based on a set of hypotheses that agree with various observations

Law: a summary of observed behavior over time that applies to many systems

Classify each of the following scientific ideas as a theory or a law. Give a one-sentence explanation as to your classification. After the class discussion, write the scientific name of each idea.

Name of Scientific Principle	Theory or Law?	Description of Scientific Principle
Evolution	Theory	Change occurs over time in populations through mutation to develop new species
Law of Conservation of Mass	Law	The total mass of reactants of a chemical reaction will equal the total amount of products of the reaction
Kinetic Molecular Theory	Theory	Gases are composed of small particles in constant, straight-line motion that experience elastic collisions when they collide and are neither attracted nor repelled by each other
Law of Definite Proportions	Law	A given compound always contains exactly the same proportion of elements by mass
First Law of Thermodynamics	Law	The energy of the universe is constant
VSEPR (Valence Shell Electron Pair Repulsion) Theory	Theory	Molecular shape can be predicted based on the number of bonding and nonbonding pairs of electrons of the central atom of a molecule
Quantum Theory	Theory	Describes the behavior of electrons as wavelike and describes the probable location of them around the nucleus

The Big Bang Model of the Origin of the Universe: Assignment and Website List

Assignment

1. Evaluate sources: Choose two sources from this list and one that you find that relate to our study of the Big Bang. Evaluate each source as to credibility and reliability. Complete checklist form "Evaluating Sources" and write one paragraph (6–9 sentences) that explains your reasoning for rating the source as you did.
2. Read Homefun Assignment (site url below). Complete discussion log for next class.
3. Participate in class discussion and pay attention to demonstrations.
4. Collaborate with your group to develop your lines of evidence for the Big Bang using the required sites and one other.
5. Write your three-part (five paragraph) essay: The Big Bang Theory of the Origin of the Universe.

Homefun Reading: Complete Discussion Log for website and One Universe reading *One Universe* Reading p. 171–178, http://ssscott.tripod.com/BigBang.html *Description of the creation of our universe as well as description of evidence of the theory. Includes citations and bibliography.*

Required Sites

http://www.discover.com/issues/oct-92/features/thefingerprintof136/ *Article outlining information related to Big Bang*

http://www.damtp.cam.ac.uk/user/gr/public/bb_home.html *Four pillars of the Big Bang, proposes unanswered questions*

http://map.gsfc.nasa.gov/m_uni.html *Outlines measurable evidence for Big Bang, goes beyond Big Bang theory, proposes where theory is weak and what else needs to be explained*

http://image.gsfc.nasa.gov/poetry/ask/a10563.html *Is Big Bang Theory true like 1+1=2 is? Theories are always tested observationally...no way to prove a theory*

Extension Sites

http://archive.ncsa.uiuc.edu/Cyberia/Expo/cosmos_nav.html *Map of site that includes universal discussions, good movies as support*

http://image.gsfc.nasa.gov/poetry/ask/acosmbb.html Ask a space scientist list of questions

http://www.discover.com/issues/dec-02/cover/ *Discusses the creation of matter in the universe beyond hydrogen and helium. Computer simulation to predict the evidence we should find.*

Discussion Preparation Log

Name ____

Period ____________________ Due Date ____________________

Article Title ____

Author(s) ____

While reading the article, highlight words or phrases that require definitions or clarifications.

Individual Assignment

What are the AUTHOR'S **major** ideas, **concepts** or **key points?**

- List these, point by point, and circle any you feel need discussion.

- Summarize the AUTHOR'S main point or idea in a brief paragraph.

- Write a reaction paragraph to the article stating your own thoughts on the topic, using specific citations from the article to support your views.

- Be ready to read your reaction paragraph in class on the due date.

Evidence of the Big Bang (100 Points)

Big Bang Essay Rubric

Cover Page **Required or -5**

Statement of the Problem (Paragraph 1) **(10 points maximum)**

- Includes underlined hypothesis, interesting & engaging *(+10)*
- Includes underlined hypothesis, somewhat interesting & engaging, *(+8)*
- Lacks underlined hypothesis, uninteresting/not engaging *(+6)*
- Lacks underlined hypothesis, but interesting & engaging, short of appropriate length, irrelevant *(+4)*

Background Information (Evidence Line/Paragraph 2) **(20 points maximum)**

- Clear, concise and convincing explanation of line of evidence to support Big Bang; presents strong evidence to support hypothesis; displays discretion between relevant information and trivial facts; comments on validity of research materials; well researched, organized, interesting *(+20)*
- Clear, convincing explanation of line of evidence to support Big Bang Theory; presents evidence sufficiently relevant to the question; displays some discretion between relevant information and trivial facts; adequately researched and moderately interesting *(+18)*
- Disconnected, vague explanation; unpersuasive evidence is unclear; presents research weakly relevant to the question; displays some discretion between relevant information and trivial facts; adequately researched *(+16)*
- Lacks explanation of evidence or presents research irrelevant to the question; displays little discretion between relevant information and trivial facts; poorly researched *(+6)*

Background Information (Evidence Line/Paragraph 3) **(20 points maximum)**

- Clear, concise and convincing explanation of line of evidence to support Big Bang; presents strong evidence to support hypothesis; displays discretion between relevant information and trivial facts; comments on validity of research materials; well researched, organized, interesting *(+20)*
- Clear, convincing explanation of line of evidence to support Big Bang Theory; presents evidence sufficiently relevant to the question; displays some discretion between relevant information and trivial facts; adequately researched and moderately interesting *(+18)*
- Disconnected, vague explanation; unpersuasive evidence is unclear; presents research weakly relevant to the question; displays some discretion between relevant information and trivial facts; adequately researched *(+16)*
- Lacks explanation of evidence or presents research irrelevant to the question; displays little discretion between relevant information and trivial facts; poorly researched *(+6)*

Background Information (Evidence Line/Paragraph 4) **(20 points maximum)**

- Clear, concise and convincing explanation of line of evidence to support Big Bang; presents strong evidence to support hypothesis; displays discretion between relevant information and trivial facts; comments on validity of research materials; well researched, organized, interesting *(+20)*
- Clear, convincing explanation of line of evidence to support Big Bang Theory; presents evidence sufficiently relevant to the question; displays some discretion between relevant information and trivial facts; adequately researched and moderately interesting *(+18)*

- Disconnected, vague explanation; unpersuasive evidence is unclear; presents research weakly relevant to the question; displays some discretion between relevant information and trivial facts; adequately researched *(+16)*
- Lacks explanation of evidence or presents research irrelevant to the question; displays little discretion between relevant information and trivial facts; poorly researched *(+6)*

Conclusion (Paragraph 5) **(10 points maximum)**

- Clearly states acceptance/rejection of hypothesis; clearly explains why hypothesis is accepted or rejected; conclusions solidly based on researched evidence, commentary leads up to conclusions, clearly communicated *(+10)*
- Clearly states acceptance/rejection of hypothesis; adequately explains why hypothesis is accepted or rejected; conclusions solidly based on researched evidence, commentary somewhat leads up to conclusions, communicated adequately, gaps in reasoning *(+8)*
- Whether hypothesis accepted/rejected is unclear; somewhat explains why hypothesis is accepted or rejected; conclusions weakly based on researched evidence, commentary does not lead up to conclusions, poorly communicated, lacks reasoning for conclusion *(+5)*
- No conclusions *(+0)*

Citations **(5 points maximum)**

- Always uses proper APA format, always represent the ideas or words of others, always used appropriately, demonstrates balanced number of citations from each source *(+5)*
- Often uses proper APA format, mostly represent the ideas or words of others, often used appropriately, somewhat demonstrates balanced number of citations from each source *(+4)*
- Occasionally uses proper APA format, occasionally/randomly represent the ideas or words of others, occasionally used appropriately or random usage, poorly balanced number of citations from each source *(+3)*
- Rarely/randomly uses proper APA format, rarely represent the ideas or words of others, rarely used appropriately, does not balanced number of citations from each source *(+2)*

Works Cited & Quality of Sources (min of 3 sources) **(15 points maximum)**

- High quality scientific sources: published within last 10 years, mostly primary sources, shows different types of sources, all sources are credible and authored at appropriate level, each source provides extensive information used in paper, demonstrates exceptional research effort; all works cited entries are formatted correctly *(+15)*
- Good quality scientific sources: published within last 20 years, shows some different types of sources, most sources are credible and authored at appropriate level, each source provides ample information used in paper, demonstrates satisfactory research effort; majority of works cited entries are formatted correctly *(+12)*
- Fair quality scientific sources: published within last 20 years, shows mostly same types of sources, most sources are biased, audience below acceptable level, source provides limited information, demonstrates fair research effort; majority of works cited entries are formatted incorrectly *(+10)*
- Poor quality sources: most sources written for inappropriate audience, not recent, display obvious bias, source provides extremely limited information, poor research effort; majority of works cited entries are formatted incorrectly *(+5)*

Overall Impressions and Comments:

"If districts are serious about getting kids up to speed academically, they should greatly expand their AVID class offerings. The wildly successful program has been helping at-risk students make the most of their academic potential for more than two decades…the very students whom most school districts are trying without much success to bolster. Success is standard procedure for AVID graduates…The program is so solid that AVID students in California have been 'knocking the socks off' their counterparts on the exit exam…"

—*San Diego Union-Tribune* Editorial, March 16, 2004