DOCUMENT RESUME

ED 352 257 SE 053 250

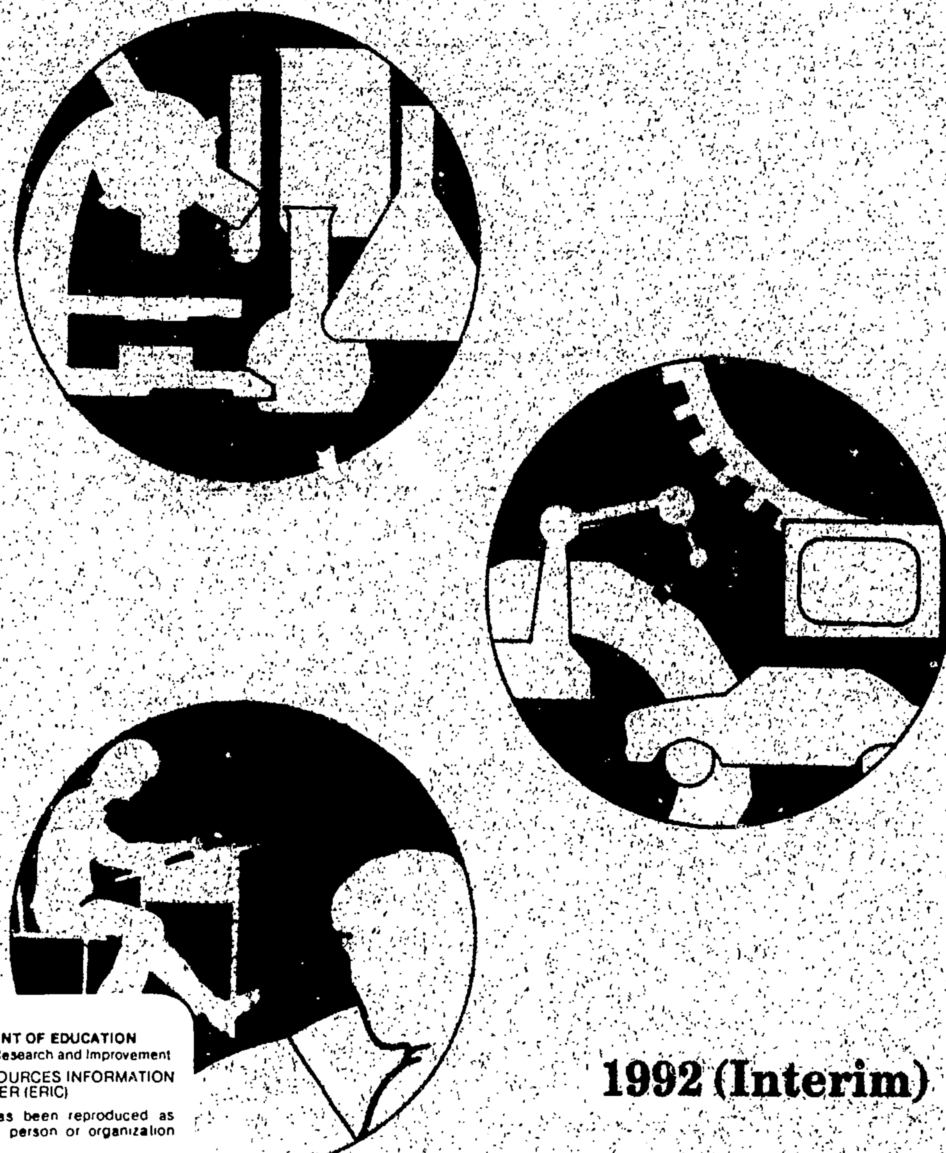
TITLE	Senior High Science: Teacher Resource Manual, 1992 (Interim).
INSTITUTION	Alberta Dept. of Education, Edmonton. Communications Branch.
PUB DATE	92
NOTE	399p.; For the Science 10 teacher resource manual, see SE 053 251.
PUB TYPE	Guides - Classroom Use - Teaching Guides (For Teacher) (052)
EDRS PRICE	MF01/PC16 Plus Postage.
DESCRIPTORS	Concept Formation; Cooperative Learning; Educational Change; Educational Resources; Evaluation Methods; Foreign Countries; High Schools; Integrated Curriculum; Language Skills; *Learning Theories; Science and Society; *Science Curriculum; *Science Education; *Science Instruction; Secondary School Science; *Teaching Methods; Technology
IDENTIFIERS	Alberta; Project 2061 (AAAS); Science Process Skills

ABSTRACT

This manual is designed to provide teachers with practical information to assist them as they implement the new science programs in their classrooms. A number of factors have influenced the development of the Alberta Senior High School Science Program. The Alberta Education policy paper, "Secondary Education in Alberta" (1985); the Science Council of Canada report, "Science for Every Student" (1984); and the American Association for the Advancement of Science report "Science for All Americans" (1989), were very influential in setting the goals, objectives and structure of the program of studies. The goal of scientific literacy achieved through emphasis on the interactions among science, technology, and society (STS), shaped the program of studies. This manual contains the following sections: "Science Classrooms into the 21st Century," "Teaching Strategies," "Preparation and Planning," "Assessment and Evaluation," and "Resources." The following essays are included in the section of teaching strategies: "Teaching for Thinking," "Teaching for Conceptual Change," "Teacher as Facilitator," "Questioning Techniques," "Cooperative Learning," "Language for Thinking and Communication," "Effective Use of a Research Process," "Periodicals in the Classroom," "An STS Context," "Controversial Issues," "Thematic Approach," "Environmental Approaches," "Agricultural Connections," "Technology and Media," "Traditional and Local Knowledge," "Teaching with Gender Balance," and "'Microchemistry' and Responsible Disposal." (PR)

SENIOR HIGH SCIENCE

Teacher Resource Manual



1992 (Interim)

Curriculum Branch

Alberta EDUCATION

ACKNOWLEDGEMENTS

Alberta Education expresses its appreciation to those individuals and groups who assisted in the development and production of this manual and acknowledges the contribution of the following:

Administration

Lloyd Symyrozum	Director, Curriculum Branch, Alberta Education
Morris Treasure	Assistant Director, Curriculum Branch, Alberta Education
Raja Panwar	Program Manager, Secondary Science, Curriculum Branch, Alberta Education

Senior High School Science Advisory Committee

Honourable Jim Dinning	Minister of Education, Ex-Officio
Dr. Roger Palmer	Assistant Deputy Minister, Alberta Education
Erich Berndt	Alberta Teacher's Association
Brian Bietz	Energy Resources Conservation Board
Rae Campbell	Association of Professional Engineers, Geologists and Geophysicists of Alberta
George Cormie	Alberta Teachers' Association
Ken Dick	Conference of Alberta School Superintendents
Dr. Joe Freedman	Alberta Medical Association
Dr. John Gray	University of Alberta, Department of Physics
John James	Southern Alberta Institute of Technology
Harold Millican	Citizen at Large
Dr. Rick Mrazek	University of Lethbridge, Faculty of Education
Dr. Douglas Roberts	University of Calgary, Faculty of Education
Linda Robertson	Alberta Federation of Home and School Associations
Keith Roscoe	Grande Prairie Regional College
Sharon Thomas	Citizen at Large
Peggy Valentine	Alberta School Trustees' Association

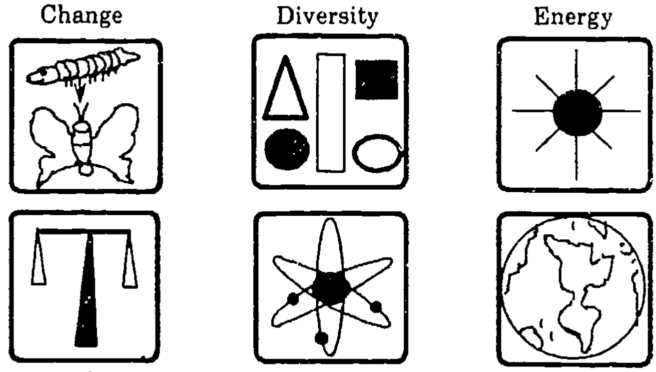
Project Coordinator

Bev Romanyshyn	Curriculum Branch, Alberta Education

Theme Icon Designers
Sturgeon Composite High School

Dwayne Germaine	Change
Chris Weiss	Diversity
Steven Daigle	Energy
Erik Pasay	Equilibrium
Darcy Kennett	Matter
Sean O'Brien	Systems

Change Diversity Energy



Equilibrium Matter Systems

Writers

Dr. Margaret Ann Armour	Department of Chemistry, University of Alberta
David Blades	Department of Secondary Education, University of Alberta
Tara Boyd	Dickensfield Junior High School Edmonton School District No. 7
Dr. Audrey Chastko	Department of Curriculum Instruction, University of Calgary
Daryl Chichak	Curriculum Resource Bank, Sherwood Park
Terry Grier	Alberta Distance Learning Project, Alberta Education
Desiree Hackman	Curriculum Branch, Alberta Education (Sturgeon School Division No. 24)
Gloria Hodgetts	Strathcona Composite High School, Edmonton School District No. 7
Yvonne Johnston	Student Evaluation Branch, Alberta Education
Dave Jordan	Curriculum Branch, Alberta Education
Dr. Heidi Kass	Department of Secondary Education, University of Alberta
Dr. Oliver Lantz	Curriculum Branch, Alberta Education (Edmonton School District No. 7)
Linda McClelland	William Aberhart High School, Calgary Board of Education No. 19
Dr. Rick Mrazek	University of Lethbridge, Faculty of Education
Ed Nicholson	Deputy Superintendent, Lakeland School District No. 5460
Bob Ritter	Department of Secondary Education, University of Alberta (RCSSD No. 7)
Dr. Wally Samiroden	Department of Secondary Education, University of Alberta
Pamela Shipstone	Alberta Distance Learning Centre, Alberta Education
Karen Slevinsky	Harry Ainlay Composite High School, Edmonton School District No. 7
Jennifer Smith	Victoria Composite High School, Edmonton School District No. 7

Reviewers

Alberta Education, Alberta Distance Learning Centre

Pamela Shipstone	Resource Consultant

Alberta Education, Curriculum Branch

George Cormie	Program Consultant, Biology 20–30 (Leduc School District No. 297)
Desiree Hackman	Resource and Implementation Consultant (Sturgeon School Division No. 24)
Dr. John Hoddinott	Program Consultant, Biology 20–30 (University of Alberta)
Bob Holzer	Program Consultant, Physics 20–30 (Edmonton School District No. 7)
Dr. Oliver Lantz	Program Consultant, Science 10–20–30 (Edmonton School District No. 7)
Bob Ritter	University of Alberta, Practicum Associate (RCSSD No. 7)
Stella Shrum	Program Consultant, Chemistry 20–30

Alberta Education, Student Evaluation Branch

Craig Emter	Test Development Specialist
Lowell Hackman	Test Development Specialist
Yvonne Johnston	Coordinator Math/Science Diploma Examination
Don Loerke	Test Development Specialist

Alberta Education, Regional Office Science Education Consultants

Blain Askew	Grande Prairie Regional Office
Greg Thomas	Calgary Regional Office
Wilf Green	Edmonton Regional Office
Ken Kluchky	Edmonton Regional Office
Fred Nordby	Red Deer Regional Office
Terry Rusnack	Lethbridge Regional Office

External

Dr. Audrey Chastko	Department of Curriculum and Instruction, University of Calgary
Bob Ritter	Practicum Associate, University of Alberta (RCSSD No. 7)

Editors

Noeline Bridge	Curriculum Branch, Alberta Education
Lisa McCardle	Curriculum Branch, Alberta Education
Barbara McCord	Curriculum Branch, Alberta Education

Desktop Publishing

Shelley Gauthier	Curriculum Branch, Alberta Education
Dianne Hohnstein	Curriculum Branch, Alberta Education
Tania Pander	Curriculum Branch, Alberta Education
Ruby Watmough	Curriculum Branch, Alberta Education

Validators

Senior High Science Field Validation Teachers (approximately 100 from 29 Alberta High Schools)

TABLE OF CONTENTS

Acknowledgements

Section 1 Introduction

Preface

Background to the Senior High Science Program
Dr. Oliver Lantz, Curriculum Branch, Alberta Education

Senior High Science Programs of Study

Vision Senior High Science Programs

Program Rationale and Philosophy

General Learner Expectations

Section 2 Science Classrooms into the 21st Century
Dr. Wally Samiroden, University of Alberta

Section 3 Teaching Strategies

3A Teaching for Thinking
David Blades, University of Alberta

3B Teaching for Conceptual Change
Dr. Heidi Kass, University of Alberta

3C Teacher as Facilitator
Dr. Audrey Chastko, University of Calgary

3D Questioning Techniques
Ed Nicholson, Deputy Superintendent
Lakeland Public School District No. 5460

3E Cooperative Learning
Dr. Audrey Chastko, and Olenka Bilash,
University of Calgary

3F Language for Thinking and Communication
Tara Boyd, Edmonton School District No. 7

3G Effective Use of a Research Process
Teddy Moline, Curriculum Branch, Alberta Education

3H Periodicals in the Classroom
Desiree Hackman, Curriculum Branch, Alberta Education

3I An STS Context
Bob Ritter, University of Alberta (RCSSD No. 7)

3J Controversial Issues
Bob Ritter, University of Alberta (RCSSD No. 7)

3K Thematic Approach
David Blades, University of Alberta

3L Environmental Connections
Dr. Rick Mrazek, University of Lethbridge

3M Agriculture Connections
Daryl Chichak, Curriculum Resource Bank

3N Technology and Media
Dave Jordan, Curriculum Branch, Alberta Education

3O Traditional and Local Knowledge
From Junior High Science Curriculum Document
NWT Education and Dr. Gloria Snively

3P Teaching with Gender Balance
Jennifer Smith, Edmonton School District No. 7

3Q "Microchemistry" and Responsible Disposal
Dr. Margaret Ann Armour, University of Alberta

Section 4 **Preparation and Planning**
Desiree Hackman, Curriculum Branch, Alberta Education

Section 5 **Assessment and Evaluation**
Karen Slevinsky, Edmonton School District No. 7
Terry Grier, Alberta Distance Learning Centre, Alberta Education

Section 6 **Resources**
Desiree Hackman, Curriculum Branch, Alberta Education
Pamela Shipstone, Alberta Distance Learning Centre, Alberta Education
Basic, Teaching, Support and other Resources

PREFACE

The *Senior High Science Teacher Resource Manual* is designed to provide teachers with practical information to assist them as they implement the new science programs in their classrooms. The planning, teaching and evaluation strategies in teacher resource manuals are **suggestions** only and are not mandated. The program of studies for each particular subject outlines what teachers are **required** to teach. The program of studies for each subject is included within each respective teacher resource manual (for ease of reference).

Portions taken directly from these legally mandated documents will appear in boxes surrounded by a broken line - - - - within this and all other interim teacher resource manuals. The Vision statement and the General Learner Expectations are common to all senior high science programs and are included in this manual. They are not repeated in the individual subject manuals which will include only the Specific Learner Expectations for a particular course/program. A senior high science teacher will find it useful to have both the *Senior High Science Teacher Resource Manual* and the appropriate subject-specific manuals. The two are designed to work together, avoiding repetition of material common to all science programs.

The following teacher resource manuals (TRMs) support the senior high science curricula.

Science 16–26 TRM (Final)
Science 14–24 TRM, 1989 (Final)

Senior High Science TRM,
June 1992 (Interim)
June 1994 (Final)

Science 10 T R M, June 1992 (Interim)
Science 20 TRM, June 1993 (Interim),
Science 10–20–30 TRM, June 1994 (Final)

Biology 20 TRM, June 1993 (Interim)
Biology 20–30 TRM, June 1994 (Final)

Chemistry 20 TRM, June 1993(Interim),
Chemistry 20–30 TRM, June 1994 (Final)

Physics 20 TRM, June 1993 (Interim),
Physics 20–30 TRM, June 1994 (Final)

During the field validation of these programs, field validation teachers have been encouraged to provide suggestions for improvement of these documents based on their experience of the new programs. All manuals will be kept in interim form until the completion of the three-year field validation period in June, 1994. During the field-validation implementation period, interim teacher resource manuals will be available through the Learning Resources Distributing Centre as they are developed.

All manuals will be divided into sections with each section paginated separately. This facilitates the revision and rearrangement of the interim documents.
Should you have any suggestions for improvement of this document please contact:

Bev Romanyshyn,
Project Coordinator, Curriculum Branch
Devonian Building, West Tower, 11160 Jasper Avenue
Edmonton, Alberta, T5K 0L2.

Telephone: 427–2984
Fax: 422–3745

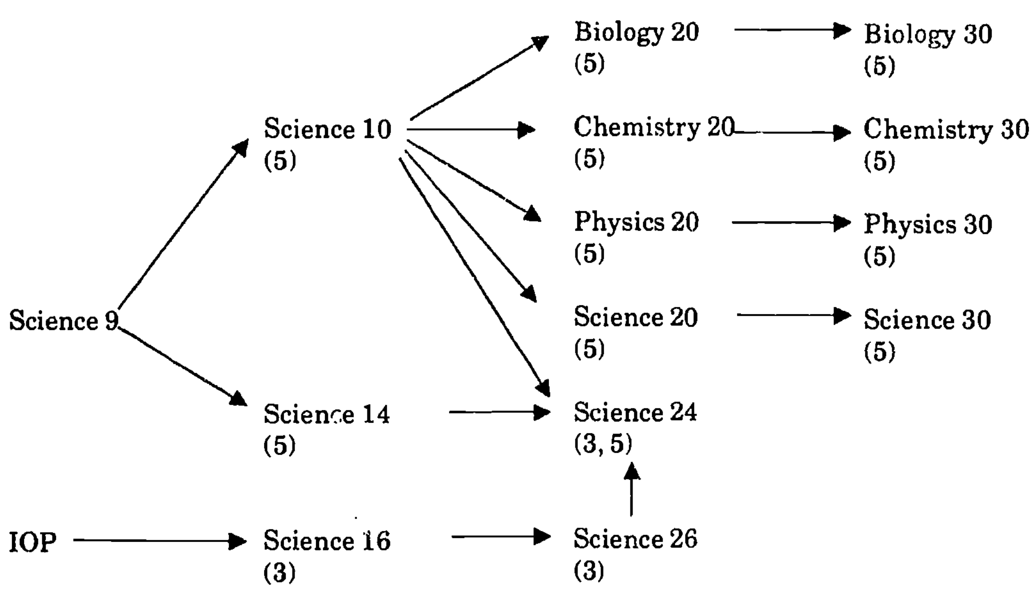
BACKGROUND TO THE SENIOR HIGH SCIENCE PROGRAM

by Dr. Oliver Lantz

A number of factors have influenced the development of the Alberta Senior High Science Program. The Alberta Education policy paper, *Secondary Education in Alberta* (1985); the Science Council of Canada report, *Science for Every Student* (1984); and the American Association for the Advancement of Science report, *Science for All Americans* (1989), were very influential in setting the goals, objectives and structure of the program. The goal of scientific literacy for all students, achieved through emphasis on the interactions among science, technology and society (STS), shaped the program of studies. Consideration of the cognitive development of students had a strong influence on selecting and sequencing topics in the program; on developing and selecting resources; and on writing suggested activities for the teacher resource manual.

The goal of scientific literacy for all students, achieved through emphasis on the interactions among science, technology and society (STS), shaped the program of studies.

The various course sequences in the Senior High Science Program with the credit values indicated in brackets are shown below.



In 1984, Alberta Education undertook a comprehensive review of secondary education in the province. The review of secondary programs in Alberta resulted in a policy statement, *Secondary Education in Alberta*, published in June 1985. The policy statement set the requirements for high school graduation and stated that a minimum of three science courses (15 credits) would be required for the Advanced High School Diploma. The review of secondary education in Alberta resulted in the development of a new program, 10-20-30, designed to provide a well-rounded science education for those students who choose to take the minimum science credits required for the Advanced High School Diploma.

The Alberta secondary education review provided the opportunity for submissions from a wide range of individuals and groups within the education community and from the general public. A Ministerial Advisory Committee was appointed to review the submissions and formulate a number of recommendations for change. Regarding science, the Ministerial Advisory Committee made the following observation:

The public supports the study of science as an important discipline and recognizes the impact and influence of science on our daily lives.

> "The public supports the study of science as an important discipline and recognizes the impact and influence of science on our daily lives through its application in industry, agriculture, forestry, and other areas vital to Alberta's social and economic welfare. The role of science in society needs to be emphasized, with consideration given to the application of science, the social and environmental impact of scientific discoveries, and the moral and ethical issues which accompany the use of scientific knowledge."

The policy statement, *Secondary Education in Alberta*, directed the new high school science program to emphasize basic scientific concepts and principles as well as their application in our world. As a result of this policy, Alberta's new secondary science program emphasizes the interrelationship of science, technology and society. The aim of the STS approach is to provide the students of Alberta with a more balanced science education, an aim that has the support of educators across Canada and around the world.

SCIENCE, TECHNOLOGY SOCIETY AND CURRICULUM

In 1984, the Science Council of Canada published a report, *Science for Every Student: Educating Canadians for Tomorrow's World*, based on a four-year study of science education in Canada. One of the central recommendations of the report was that, "science should be taught at all levels of school with an emphasis and focus on the relationship of science, technology and society (STS) in order to increase the scientific literacy of all citizens" (p. 38). The Science Council's recommendations are consistent with the objectives of the international STS movement. For over a decade, educators in Australia, Britain, the United States and Canada have expressed concern that current secondary science programs are too narrow and that science is being taught in a way that makes it irrelevant to students. Previous secondary school science programs tended to emphasize the theoretical aspects of the structure of the discipline while doing little to teach students how science, technology and society are related. The STS approach broadens the basis of science education by integrating into the science program accurate presentations of the nature of science, the nature of technology and their interactions with each other and with society.

Technology is often the main point of contact individuals have with science.

To develop scientifically literate and responsible citizens, teaching must centre on students' development as thinking and caring members of society, rather than focusing on a body of knowledge isolated from its social context. It is crucial to society that scientific knowledge is used wisely, with due regard for the welfare of all members of society. The knowledge necessary for responsible action is most effectively gained by students who are convinced of its relevance. In other words, an STS emphasis in science education accomplishes three things: it helps ensure that students become both scientifically literate and socially responsible, and it motivates students to learn about science.

Technology is often the main point of contact individuals have with science. High school students are intrigued by the ever-developing gadgets and processes that characterize our age. There is therefore a tremendous opportunity, when dealing with the relationship between science and technology, to make the subject come alive. Science deals with gravity and friction, but technology gives us the wheel. While science asks "why?", technology asks "how?". Science is aimed at increasing human understanding and ability to explain nature. Technology is aimed at developing devices or processes that have practical purposes.

Science and technology affect every aspect of the daily life of Canadians. Both science and technology are involved in areas as diverse as communications, travel, agriculture and waste management. But what is science and what is technology? Are they the same or are they different? How do science and technology affect society? How does society control science and technology? If students are to become enlightened, contributing citizens in a constantly changing society they will need to know the answers to these questions.

Scientific literacy is an important goal of secondary school education, as it provides a means for asking and answering some very important questions.

Scientific literacy is an important goal of secondary school education, as it provides a means for asking and answering some very important questions.

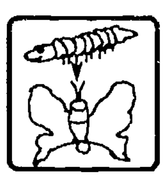
A scientifically literate person has the following characteristics:

- demonstrates a working knowledge and practical understanding of the sciences
- has the ability to evaluate scientific evidence
- understands the processes by which scientific knowledge is developed and can adapt those processes for personal use
- applies science concepts, theories and processes to the investigation of everyday problems
- understands the relationship between science and technology
- demonstrates awareness of how science and technology can function responsibly in a social context
- recognizes the limitations as well as the usefulness of science and technology in advancing human welfare
- demonstrates a continuing interest in science and technology.

The Senior High Science Program is designed to develop in students the characteristics of a scientifically literate person.

THEMES

Themes provide a means of showing the connections among science disciplines and sub-disciplines within all new senior high science programs. The six themes of senior high science — change, diversity, energy, equilibrium, matter and systems — are big ideas of science that link the theoretical structures of the scientific disciplines. Themes provide a framework for teachers to show students how parts of what they are learning fit together; to focus on the big ideas of science; and to reinforce the importance of understanding ideas and fundamental concepts of science.

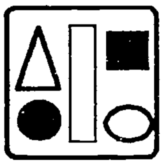


Change

In our study of change we often focus on what remains constant.

Understanding the patterns and causes of change helps us make predictions and, to some extent, control change. Changes can be steady, cyclical or irregular and systems or processes may show more than one kind of change. In our study of change we often focus on what remains constant; for example, conservation of mass, conservation of energy and conservation of charge.

Cyclical changes, while common to living systems, can also be found in feedback systems, periodicity, climate, cycles of water, nitrogen, carbon and oxygen. In Earth science, change manifests tectonic cycles of mountain building, plate movement and subduction. In chemistry, chemical changes in reactions are obvious examples. In physics, changes in energy, momentum and position of objects due to gravity are some examples. Evolution is change with a direction: time. Life forms have evolved, as has Earth and, indeed, the universe. Evolution is a central organizing principle of life sciences.

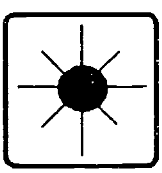


Diversity

Diversity refers to the wide array of living and non-living matter. Diversity is often the result of change. Understanding diversity helps us to classify and distinguish the various forms of living and non-living matter and their interrelationship. While matter exists in a variety of forms, there is a common fundamental, underlying structure.

Diversity refers to the wide array of living and non-living matter. Diversity is often the result of change.

Matter exists in a variety of forms, elements and compounds in chemistry, the subatomic particles in physics, and types of rocks in geology. Diversity in living systems is important to human beings. We depend upon food webs to obtain the necessary energy and materials for life. While minor disruptions to food webs may be reversible, major disruptions could result in changes that cannot be reversed. The variety of Earth's life forms is apparent not only in the anatomical and behavioural similarities and differences among organisms, but also from the study of similarities and differences among molecules. For example, the DNA molecules link just four kinds of smaller molecules, but it is their precise sequence that erodes genetic information. The closeness or remoteness of organisms can be inferred from the DNA sequence.



Energy

Energy exists in many forms. Energy provides living systems with the ability to grow and reproduce, and underlies all chemical and physical changes. The understanding of energy is basic to the explanation of processes as diverse as metabolism, weather, continental movement and nuclear reactions.

Energy provides living systems with the ability to grow and reproduce, and underlies all chemical and physical changes.

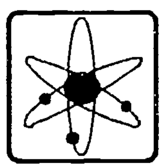
This theme pervades the physical and biological sciences linking various disciplines. Many of the phenomena studied in the physical sciences involve conversions from one energy form to another. In biological sciences, the flow of energy drives metabolism, growth and development. The flow of energy in ecosystems determines how organisms interact through the trophic levels of communities. The First and Second Laws of Thermodynamics apply to all energy changes occurring in nature.

Equilibrium

Equilibrium can be static or dynamic, but in both instances a counterbalance to change is established.

Equilibrium is a state in which opposing forces or processes are balanced or appear to have stopped and will remain so until change is imposed on the system. The idea of equilibrium helps us understand and make predictions about imposed changes on such things as the ecosystem, homeostatic mechanisms, chemical reactions and balanced forces.

The theme of equilibrium can be applied to systems that have settled to a steady state. For example, when a rock falls and comes to rest, all forces are balanced and all processes of change appear to have stopped. In ecosystems where members of every species are dying at the same rate at which they are reproducing, an equilibrium has been established. Equilibrium can be static or dynamic, but in both instances a counterbalance to change is established. Feedback is an important element in keeping some systems, such as the human body, in a state of equilibrium. Such mechanisms may fail if conditions fall outside the usual range of functioning.



Matter

Just as energy undergoes change and is found in many forms. matter can be viewed as being atoms and molecules that can recombine in a variety of ways to produce new forms.

Matter makes up the physical world and, like energy, it exists in a variety of forms. Yet, in spite of appearances, everything is made up of relatively few kinds of basic components combined in various ways. Just as energy undergoes change and is found in many forms, matter can be viewed as being atoms and molecules that can recombine in a variety of ways to produce new forms. In chemistry, the understanding of the subatomic structure and chemical bonding provide insight into the behaviour of many physical systems. Changes to atomic nuclei are related to the basic structure of matter, and the effects could range from fission to fusion, or the transmutation of elements to synthesis of new elements.

The behaviour of matter is dependent upon its physical state and underlies phase transformations, pressure, water waves, sound waves, earthquakes, temperature change and Brownian motion. In biology, the behaviour of matter in a fluid state leads to a better understanding of blood circulation, respiration and the function of organs such as the kidney. The function of DNA, too, is linked to an of molecules and their arrangement which encodes genetic information. It is this genetic instruction that governs the functions of a cell.

In ecosystems, matter in the form of carbon, nitrogen, phosphorus and oxygen is recycled and conserved. Thus, in a food web, matter is synthesized and consumed with accompanying changes in energy. Since organisms are dying and decaying at the same rate as new life is being synthesized the total living biomass is constant and there is a cyclic flow of matter from old to new life.

Systems

Thinking in terms of systems allows us to make sense of the parts, how the parts interact, and the manner in which one system interacts with another.

Objects, organisms, processes, machines, or any collection of things that have some relationship or influence on one another, can be thought of as a system. Thinking in terms of systems allows us to make sense of the parts, how the parts interact, and the manner in which one system interacts with another. Whether an ecosystem or a solar system is being studied, we must include sufficient parts so that their relationship to one another makes sense. For example, if we wish to study energy flow in an ecosystem we would include solar energy input and the decomposition of dead organisms, while ignoring the predator-prey relationships.

Systems have inputs and outputs. For example, air and fuel go into an engine; exhaust, heat and mechanical work are outputs. Part of the output may be fed into another part. Generally, such feedback serves as a control, and homeostatic mechanisms are an example.

QUANTIFICATION IN THE SCIENCES

Mathematics permeates all sciences, especially the applied sciences. In science, mathematics provides tools to analyze data and discover patterns and relationships. In physical sciences, mathematics is the language and provides the rules for the rigorous analysis of scientific ideas and data. Fundamental processes of quantification recur in science in order to transform abstract ideas into concrete application. To advance the understanding of transformation of matter, energy, change and equilibrium, quantification is necessary.

Quantification can provide a shorthand way of communicating an idea in the form of a precise statement of the quantitative relationships among variables, and make possible generalizations in numerical, symbolic and graphical form. It enables the creation of models, which help scientists in other disciplines search for new structures and insights.

COGNITIVE LEVEL

Bloom's taxonomy can be used to determine the cognitive level necessary for students to perform particular tasks—knowing, comprehending, applying, analyzing, synthesizing or evaluating.

Bloom's Categories	Thinking Skills	Cognitive Levels
Knowledge (K)	knowledge of specific facts, terminology, concepts, procedures, techniques, theories, laws or conceptual schemes	Concrete
Comprehension (C)	identify, translate, describe, select, process,interpret, estimate, extrapolate or present information in the form of a functional relationship	Concrete
Application (Ap)	application of knowledge and methods of science to unfamiliar problems	High concrete or low formal
Analysis (An)	analyze, recognize, interpret, evaluate and relate various problems, statements, theories, laws, situations or models	High concrete or low formal
Synthesis (S)	deduce, derive, formulate, design, revise, refine, extend, generalize, select, or produce operations, communications, experiments, models and relationships	Formal
Evaluation (E)	justify, debate, solve, recommend, judge, criticize, prove, dispute, measure, choose, validate, select, rate	Formal

When Bloom's category is specified and the cognitive level of the student is considered, appropriate teaching strategies can be designed. Many Science 10 students will be operating at the concrete operational level, with a small percentage exhibiting formal operational thinking. Thus, it is imperative that teachers attempting instruction of concepts and skills at the higher level of Bloom's categories (levels of cognition higher than those at which the majority of students are functioning) use teaching strategies that involve heavy conceptualization. These higher concepts and skills must be firmly based in the student's own experience and must be very concrete. Extension from this base must also be as concrete and personally relevant as possible.

SCIENCE

VISION
SENIOR HIGH SCIENCE PROGRAMS

The senior high science programs will help all students attain the scientific awareness needed to function as effective members of society. Students will be able to pursue further studies and careers in science, and come to a better understanding of themselves and the world around them. To achieve this, appropriate curriculum components are identified and approached from a common philosophical position in each science course. These components include expected student knowledge, skills and attitudes.

In the senior high science programs, students focus on learning the big interconnecting ideas and principles. These ideas, or major principles, originate from science knowledge that transcends and unifies the natural science disciplines. These major ideas include change, diversity, energy, equilibrium, matter and systems; the process by which scientific knowledge is developed, including the role of experimental evidence; and the connections among science, technology and society. The ideas will also form a framework for the curriculum, provide continuity with the junior high program and build on students' previous learning.

The senior high science programs place an increased emphasis on developing methods of inquiry that characterize the study of science. For example, students will further their ability to ask questions, investigate and experiment; gather, analyze and assess scientific information; and test scientific principles and their applications. They will develop their problem-solving ability and use technology appropriately. By providing students with opportunities to develop and apply these skills, they will better understand the knowledge they have acquired.

Students will be expected to show an appreciation for the roles of science and technology in understanding nature and maintain a lifelong interest in science. They will possess enthusiasm and positive attitudes toward science.

The learning context is an integral part of the senior high science programs. The context is intended to foster the expected attitudes in students, further the development of students' skills and increase students' understanding of science knowledge, science process, and the connections among science, technology and society. The context for learning will be relevant to students' lives so they will experience science as interesting and dynamic. Learning opportunities will be made meaningful by providing concrete experiences that students can relate to their world.

The senior high science programs place students at the centre. Students are active learners and will assume increased responsibility for their learning.

This framework was used for the development of programs including Science 10–20–30, Biology 20–30, Chemistry 20–30, Physics 20–30, Science 14–24 and Science 16–26. These programs have a common rationale and philosophy, goals and general learner expectations. As well, each program will have specific learner expectations and standards of achievement.

SENIOR HIGH SCIENCE

A. PROGRAM RATIONALE AND PHILOSOPHY

Science by its very nature is interesting, exciting and dynamic. Through the study of science, students are given the opportunity to explore and understand the natural world and to become aware of the importance of science to their lives. Meaningful learning takes place when the study of science relates to what learners already know, deem personally useful and consider relevant. Young people learn best from concrete experiences that present an authentic view of science. In the senior high science programs, students learn science in relevant contexts and engage in meaningful activities. This facilitates the transfer of knowledge to new contexts. Students are encouraged to participate in lifelong scientific learning and to appreciate science as a remarkable, inspiring and stimulating human enterprise with practical impact on their lives and on society as a whole.

Science is experimental, creative and imaginative; methods of inquiry characterize the study of science. In the senior high science programs, students further develop their ability to ask questions, investigate and experiment; to gather, analyze and assess scientific information; and to test scientific laws and principles and their applications. In the process, students exercise their creativity and develop critical thinking skills. Through experimentation, problem-solving activities and independent study, students develop an understanding of the processes by which scientific knowledge evolves.

The senior high science program place students at the centre. Students are active learners and will assume increased responsibility for their learning as they work through the course. A thorough study of science is required to give students an understanding of science that encourages them to make appropriate applications of scientific concepts to their daily lives. Students are expected to participate actively in their own learning; teachers act as collaborators or guides. An emphasis on the key concepts and principles of science provides students with a more unified view of the natural sciences and a greater awareness of the connections among them.

GOALS

The major goals of the senior high science programs are:

- to develop in students an understanding of the big interconnecting ideas and principles that transcend and unify the natural science disciplines
- to provide students with an enhanced understanding of the scientific world view, inquiry and enterprise
- to help students attain the level of scientific awareness that is essential for all citizens in a scientifically literate society
- to help students make informed decisions about further studies and careers in science
- to provide students with opportunities for acquiring knowledge, skills and attitudes that contribute to personal development.

The senior high science courses comprise is an integrated academic program that helps students better understand and apply the fundamental concepts and skills that are common to biology, chemistry, physics and Earth science. The focus is on helping students understand the scientific principles behind the natural events they experience and the technology they use in their daily lives. The program encourages enthusiasm for the scientific enterprise and develops positive attitudes about science as an interesting human activity with personal meaning. It develops in students the knowledge, skills and attitudes to help them become capable of, and committed to, setting goals, making informed choices and acting in ways that will improve their own lives and life in their communities.

B. GENERAL LEARNER EXPECTATIONS

The general learner expectations outline the many facets of scientific awareness and serve as the foundation for specific learner expectations. The general learner expectations are developed through the study of individual units in senior high science programs, where attitudes, skills and knowledge develop concurrently.

ATTITUDES

Students will be encouraged to develop:

- an enthusiasm for, and a continuing interest in, science
- the effective attributes of scientists at work; such as, respect for evidence, tolerance of uncertainty, intellectual honesty, creativity, perseverance, cooperation, curiosity and a desire to understand
- positive attitudes toward scientific skills involving mathematics, problem-solving and process skills
- open-mindedness and respect for others' points of view
- a sensitivity to the living and non-living environment
- an appreciation for the roles of science and technology in our understanding of the natural world.

SKILLS

Students will be expected to develop an ability to use thinking processes associated with the practice of science for understanding and exploring natural phenomena, problem solving and decision making. These processes involve many skills that are to be developed within the context of the program content.

The skills framework presented here assumes that thinking processes often begin with an unresolved problem or issue or an unanswered question. The problem, issue or question is usually defined and hypotheses formulated before information gathering can begin. At certain points in the process, the information needs to be organized and analyzed. Additional ideas may be generated—for example, by prediction or inference—and those new ideas, when incorporated with previous learning, can create a new knowledge structure. Eventually, an outcome such as a solution, an answer or a decision is reached. Finally, criteria are established to judge ideas and information in order to assess both the problem-solving process and its outcomes.

The following skills are not intended to be developed sequentially or separately. Effective thinking appears to be non-linear and recursive. Students should be able to access skills and strategies flexibly; select and use a skill, process or technology that is appropriate to the task; and monitor, modify or replace it with a more effective strategy.

- Initiating and Planning
  - identify and clearly state the problem or issue to be investigated
  - differentiate between relevant and irrelevant data or information
  - assemble and record background information
  - identify all variables and controls
  - identify materials and apparatus required
  - formulate questions, hypotheses and/or predictions to guide research
  - design and/or describe a plan for research or to solve the problem
  - prepare required observation charts or diagrams
- Collecting and Recording
  - carry out and modify the procedure, if necessary
  - organize and correctly use apparatus and materials to collect reliable experimental data

- accurately observe, gather and record data or information according to safety regulations (e.g., WHMIS) and environmental considerations

- Organizing and Communicating

  - organize and present data (themes, groups, tables, graphs, flow charts and Venn diagrams) in a concise and effective form
  - communicate data more effectively, using mathematical and statistical calculations where necessary
  - express measured and calculated quantities to the appropriate number of significant digits, and use appropriate SI units for all quantities
  - communicate findings of investigations in a clearly written report

- Analyzing

  - analyze data or information for trends, patterns, relationships, reliability and accuracy
  - identify and discuss sources of error and their effect on results
  - identify assumptions, attributes, biases, claims or reasons
  - identify main ideas

- Connecting, Synthesizing and Integrating

  - predict from data or information
  - formulate further testable hypotheses supported by the knowledge and understanding generated
  - identify further problems or issues to be investigated
  - identify alternatives for consideration
  - propose and explain interpretations or conclusions
  - develop theoretical explanations
  - relate the data or information to laws, principles, models or theories identified in background information
  - answer the problem investigated
  - summarize and communicate findings
  - decide on a course of action

- Evaluating the Process or Outcomes

  - establish criteria to judge data or information
  - consider consequences and perspectives
  - identify limitations of the data or information, and interpretations or conclusions, as a result of the experimental/research/project/design processes or methods used
  - suggest alternatives and consider improvements to experimental technique and design
  - evaluate and assess ideas, information and alternatives

Further Reading

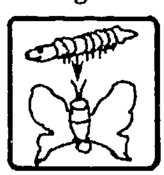
For a more detailed discussion on how to integrate thinking and research skills into the science classroom, refer to the Alberta Education publications: *Teaching Thinking: Enhancing Learning* (1990) and *Focus on Research* (1990).

KNOWLEDGE

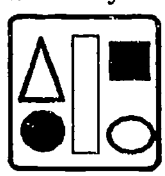
Science Themes

Students will be expected to demonstrate an understanding of themes that transcend the discipline boundaries and show the unity among the natural sciences, including:

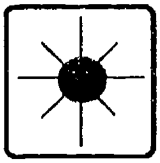
- Change: how all natural entities are modified over time, how the direction of change might be predicted and, in some instances, how change can be controlled



- Diversity: the array of living and non-living forms of matter and the procedures used to understand, classify and distinguish those forms on the basis of recurring patterns

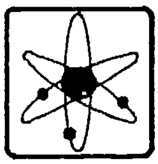


- Energy: the capacity for doing work, which drives much of what takes place in the universe through its variety of interconvertible forms



- Equilibrium: the state in which opposing forces or processes balance in a static or dynamic way

- Matter: the constituent parts and the variety of states of the material in the physical world



- Systems: the interrelated groups of things or events that can be defined by their boundaries and, in some instances, by their inputs and outputs.

Science, Technology and Society (STS)

Students will be expected to demonstrate an understanding of the processes by which scientific knowledge is developed, and of the interrelationship of science, technology and society, including:

- the central role of experimental evidence in the accumulation of knowledge, and the way in which proposed theories may be supported, modified or refuted
- the inability of science to provide complete answers to all questions
- the functioning of products or processes based on scientific principles
- the ways in which science advances technology and technology advances science
- the use of technology to solve practical problems
- the limitations of scientific knowledge and technology
- the influence of the needs, interests and financial support of society on scientific and technological research
- the ability and responsibility of society, through science and technology, to protect the environment and use natural resources judiciously to ensure quality of life for future generations.

Further Reading

For further reading on integrating science, technology and society into the classroom, refer to the Alberta Education publication: *STS Science Education: Unifying the Goals of Science Education* (1990).

SCIENCE CLASSROOM INTO THE 21ST CENTURY

By Dr. Wally Samiroden

Recent research findings resulting from questionnaire responses and dialogues with school students or high school graduates are far too consistent in reporting the growth of negative attitudes toward school science as students continue their studies from the elementary to senior high school levels and beyond. Equally disheartening are the reports of the low levels of "scientific literacy" among school students, school graduates, and the adult populations of Canada. The implementation of a more student-oriented science program is seen as a possible answer to these findings. Such a program would include studies which emphasize the interrelationships among science, technology and society, and the development of lifelong interests, intellectual curiosity, and the appreciation of science. Such studies would see significant changes in what would be seen in the science classroom of the future in terms of the subject, the students and the teacher.

Students will be developing more realistic expectations of science and technology so that they can base their future career, political, and social decisions on a sound knowledge of how science and technology function.

The content of the courses will focus on presenting a more authentic view of science. Students will be gaining scientific and technological knowledge, conceptual understandings, positive attitudes toward science, and problem-solving skills that they can transfer to their daily lives and that they can see as being relevant to their futures. Concepts and skills taught in mathematics, language arts, social studies and other programs will be applied and reinforced wherever appropriate. Studies will promote a better understanding of the nature of science. Science will be presented as a human endeavour that is subject to a social context. Students will be learning how the social and political climates can determine whether scientific activity is valued or ignored, and whether the results of research are well used. They will be developing more realistic expectations of science and technology so that they can base their future career, political, and social decisions on a sound knowledge of how science and technology function.

The science class in such programs will have busy, actively involved students who want to discuss science. They will be enthusiastic in their commitment to doing science, as demonstrated by their self-initiated identification of science-related problems, issues and investigations, and their willingness to seek appropriate solutions. Their involvements in science-related activities will exemplify cooperation rather than competition. Cooperation will be evident in the study of content, resolution of issues, research of topics, and during science investigations.

Science classroom activities will be teacher "facilitated" rather than teacher "directed" for the most part, with the teacher being a model "problem solver" rather than a presenter of facts and content detail.

Science classroom activities will be teacher "facilitated" rather than teacher "directed" for the most part, with the teacher being a model "problem solver" rather than a presenter of facts and content detail. Teachers will be well prepared to facilitate the study of the prescribed curriculum content. They will demonstrate how they use accumulated scientific and technological knowledge as well as ways by which they seek and integrate new information. They will possess and practise an extensive repertoire of teaching/learning approaches. Through self-directed, critical reflection they will actively seek ways to improve their teaching and the science program. They will provide students with plenty of opportunity to develop through practice, the skills required to become proficient at science inquiry, technological problem solving and decision making. They will be developing and using a variety of means to determine student progress toward the development of creativity, problem-solving skills, and an understanding of the interactions of science, technology and society.

Student and teacher use of media, technological resources and human resources in the classroom, in the school, in the community and in the world will be maximized. Focus on the skills of accessing and using current information will become a standard practice. Classrooms and/or resource centres have audio-visual equipment and programs, computers, modems, appropriate software, current science journals, periodicals and on-line data bases that help provide such information.

When scientific and technological concepts, principles and theories are studied through a societal context, they have more meaning and relevance.

Science-based societal and technological issues will remain prevalent as we move toward and into the 21st century. When scientific and technological concepts, principles and theories are studied through a societal context, they have more meaning and relevance. It will be through science classrooms that emphasize problem solving, basic and relevant scientific concepts and principles, the interrelationships of science, technology and society, environmental impacts of science and technology, and the moral and ethical issues which accompany the use of scientific knowledge and technologies, that future students can become scientifically literate.

Self-Assessment Checklist for Science Teachers

		Very Proficient	Satisfactory	Needs Improvement
1.	I demonstrate an attitude of open-mindedness and suspended judgment.			
2.	I am proficient in manipulating and using science laboratory equipment.			
3.	I can apply mathematics to gathering, processing and communicating data in my teaching.			
4.	I use oral and written communication skills effectively.			
5.	I understand factors affecting the physical, emotional and intellectual growth of my students.			
6.	I am an expert in the content of high school science courses.			
7.	I can motivate inquiry in my students.			
8.	I am aware of and use resources that enhance my science class.			
9.	I can describe interrelationships among science, technology and society.			
10.	I can describe energy/ecological relationships in the environment and their social and economic implications.			
11.	I try to learn about the social–economic–environmental impacts of science and the social and moral responsibilities of scientists.			
12.	I know my students well enough so that I provide unique individual experiences in science.			
13.	I effectively use current technological devices and materials in my teaching (videos, computer simulations and other audio-visuals).			
14.	I use various approaches to evaluating student progress.			
15.	I use a variety of teaching styles and organizations (e.g., student-directed inquiry, lecture, demonstration, individual and group work, convergent and divergent questioning, seminars, student presentations, simulations).			
16.	I make provisions for safety during classroom/laboratory activities and can handle emergencies should they arise.			
17.	I provide a rich learning environment (of data sources, materials for experimentation, phenomena to observe, ideas) for use by my students.			
18.	I continually revise my teaching approaches in responses to experiences, PD activities and student feedback.			

Instructions for External Evaluator Checklist on the Teaching and Learning of Science

The observation tool on the following page can only provide interpretations from the perspective of the evaluator. As such, in using it, evaluators should attempt to observe the teacher and classes during several different teaching–learning situations and possibly discuss the observed sessions with both teacher and selected students. To provide further meaningful context to the evaluation, it would be necessary for the evaluator to provide some personal academic and professional history as related to the teaching and learning of science or the topic being discussed. A suggested form for obtaining this information is given below.

Context of Class

Course ____________________ Unit _______________ Topic ________________________________

Teaching Learning Activities

____

____

Students: Males ___________ Females _________

General Academic Attitudes of Class

____

____

History of Evaluator

Teaching History: Science or Science-related Subjects

Science Courses Taught	Levels of Students Taught	Years Courses Taught (e.g., 19 ___ to 19___)

Academic/Experiential History as Related to Fields of Science

____

____

____

External Evaluator Checklist on the Teaching and Learning of Science

		Strongly Agree		Strongly Disagree	
A)	**During the teaching of Science 10, this teacher:**	**1**	**2**	**3**	**4**
1.	emphasizes conceptual understanding				
2.	stresses science facts and concepts				
3.	stresses the application of laws and principles				
4.	develops science process skills to be used as tools				
5.	emphasizes the use of problem-solving processes in personal decision making				
6.	emphasizes the relationships among the different sciences, seldom studying a single field of science and technology for an extended time period				
7.	stresses the application of the learning and the scientific processes as well as the social relevance of science and technology				
8.	provides opportunities for some student-directed investigations				
9.	encourages students to discuss science-based societal issues.				
B)	**During the study of Science 10, these students:**	**1**	**2**	**3**	**4**
1.	make and use reasonable predictions				
2.	make reasonable inferences				
3.	organize a logical sequence of thought (verbally and written)				
4.	form operational definitions				
5.	organize related concepts into broader schemes				
6.	use common scientific symbols				
7.	plan and complete data-gathering experiments				
8.	apply appropriate scientific principles in solving problems				
9.	apply science content and processes to other aspects of their lives				
10.	recognize interrelationships of scientific advances, technological applications and societal values.				

Student Perception Checklist

The checklist below focuses on gaining student perceptions to three pedagogical areas:

a. methods and content of science teaching
b. organization of science classes
c. use of science teaching/learning materials.

There are seven statements for each of the areas, and each of the statements is identified by letter. When this checklist is administered, students should be encouraged to give the first answer that "pops" into their minds. The responses can be quantified by giving each positive response (can be either agree or disagree depending on the context of the statement) a value of (3) and each negative response a value of (1). Any "not appropriate response" would be given a value of (2).

Note: a, b and c column should not appear on the student version			Agree (a)	Disagree (d)	Not Appropriate (n)
b	1.	My teacher told me a lot about science during this course.			
a	2.	I would like to learn more in science class			
b	3.	In science I mainly worked in small groups.			
a	4.	The science I learned helps me in my daily life.			
b	5.	I did more experiments in science this unit (year) than I did in the past.			
c	6.	Our science textbook is very interesting.			
c	7.	I often worked with equipment and materials in this science course.			
a	8.	Science classes should be more often.			
b	9.	I was often confused by the activities and experiments.			
c	10.	Working with science materials is more interesting than reading a textbook.			
b	11.	I enjoyed the science lessons from film/video.			
a	12.	Studying science was a waste of time.			
c	13.	Using computer programs in science was valuable.			
a	14.	I enjoy watching science programs on TV and reading about science.			
c	15.	Discussing science-related issues was valuable.			
c	16.	Science equipment is hard to use.			
a	17.	I felt dumb when I studied about things in science class.			
b	18.	I learn more in science when we do experiments.			
a	19.	In science classes, students talk more than the teacher does.			
b	20.	I learned more science in this course than in any other science course.			
c	21.	Science materials usually do not help me get the "right" answer.			

TEACHING FOR THINKING

by David Blades

THINKING ABOUT THINKING SKILLS IN SCIENCE EDUCATION

Science education affords many opportunities for students to develop their thinking skills. Science expresses in method the human impulse of curiosity, and in philosophy the human desire to know and understand. Designing research topics, inventing names for new species, building model representations are but some of the ways creativity is part of science. Exploring the relationships between science research and social demands, evaluating arguments, assessing evidence are a few ways science education can encourage students to think critically. The sheer delight of watching a butterfly emerge from a cocoon, or learning about the stars above, in a science class or on a field trip recalls to students the importance of wonder in our lives.

Thinking, of course, is an extremely complex, dynamic and integrated activity. To understand thinking better, we can look at facets of thinking as three interrelated "domains": critical thinking, creative thinking and reflective thinking. There is much debate over how these terms could be defined. For our purposes, these domains are defined *operationally*; that is, by what type of activity they encourage. For example, critical thinking can be thought of as the disposition toward analyzing and evaluating points of view with a goal of problem solving. When someone develops novel or alternative ideas, we often say they are being creative. Creative thinking can also include developing deep insights. Reflective thinking involves pondering, experiencing wonder, realizing opportunity and developing probing questions when considering ideas.

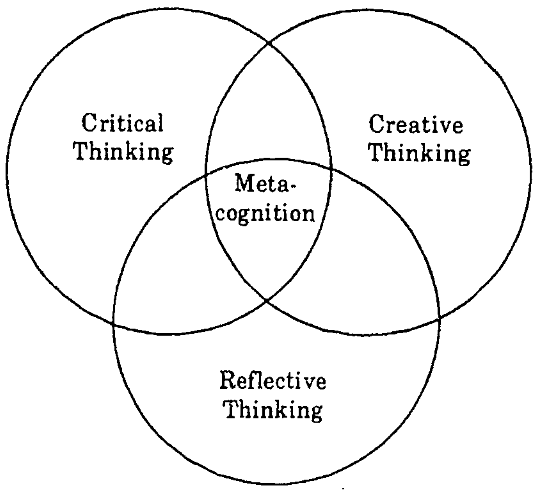
A useful definition of metacognition is "thinking about thinking".

The three domains of thinking are, of course, totally integrated in human thinking. It is possible, however, to focus on developing facets of each of these domains. Abilities in each thinking domain are called "thinking skills". Encouraging the development of thinking skills in each domain requires personal awareness of how one thinks. This awareness is called metacognition. A useful definition of metacognition is "thinking about thinking".

The following chart illustrates the relationship of the three domains of thinking and metacognition.

The Three Domains of Thinking and Metacognition

Analysis and evaluation of points of view, claims, problem resolving



Production of novel, alternative, and insightful approaches and ideas

Pondering, wondering, an openness to new ideas, recognizing opportunity

WHY TEACH THINKING SKILLS?

Teachers, however, do intuitively teach thinking skills all the time.

1. **The deliberate teaching of thinking skills encourages student cognitive growth.**

All teaching involves thinking skill development, and all science teachers encourage students to develop thinking skills to some extent. Research indicates, however, that students in high school are not developing their thinking skills to very high levels. For example, students do not often connect the learning about logarithms in mathematics to the topic of pH in chemistry. Studies have also shown that the explicit planning for critical, creative, and reflective thinking is not common. Teachers, however, do intuitively teach thinking skills all the time. For example, a teacher sharing with students tricks on how to remember biological taxonomy levels; e.g. King|Phy|C|O|Fa|Gu|S, is using a thinking skill called "pattern making". The purpose of this section of the teacher resource manual is to help teachers develop intuitive teaching of thinking skills into explicit, deliberate and planned instruction.

Research is clear that the explicit teaching of thinking skills results in improvements in students' academic performance. The active and deliberate teaching of thinking also increases the personal development of students by encouraging their creative, critical and reflective abilities. When this happens, students find increased satisfaction with their education.

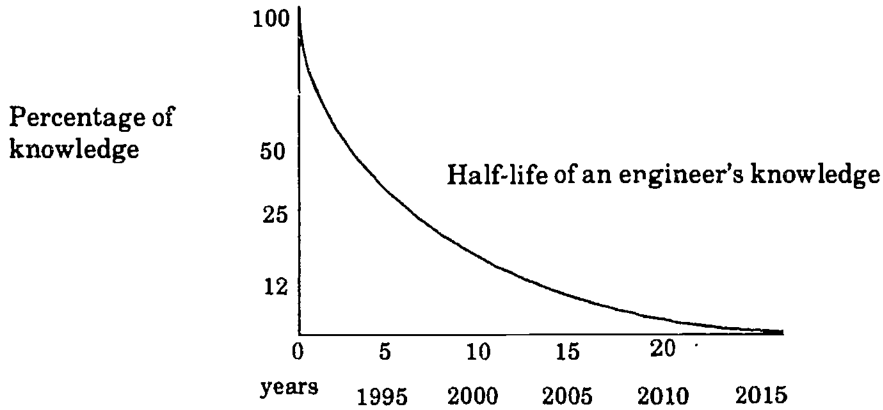
It is becoming very clear that students come to their science classes with many preconceptions and ideas which shape what they will believe and ultimately learn in science. Activities that develop thinking skill abilities, such as concept mapping, are especially useful in identifying and dealing with students' prior conceptions. A discussion about dealing with students' preconceptions is found in the Section 3B of this teacher resource manual.

It is becoming very clear that students come to their science classes with many preconceptions and ideas which shape what they will believe and ultimately learn in science.

2. **Changes in society are redefining what it means to be educated.**

Many economists and futurists describe the post-war era from 1950 to today as the "information age". Certainly, the development of ultra-small microchips has made very powerful computers available for home use; a revolution of manufacturing through robotics has already begun. Some futurists predict technological developments during the 1990s will encourage a massive leisure industry which will force formal, academic learning to be redefined as a lifelong process. The jobs of tomorrow will depend less and less on students remembering vast amounts of information, and more and more on the ability of students to access information and then use knowledge in appropriate ways. The qualified graduates of tomorrow will need to be critical, creative and reflective thinkers, able to find and use information quickly. The sheer explosion of information available to the average citizen through computers, and the ability of computers to process information, has made it impossible for a person keep up with his particular field. The following graph shows the speed at which the knowledge of an engineer graduating from post-secondary study becomes obsolete:

The qualified graduates of tomorrow will need to be critical, creative and reflective thinkers, able to find and use information quickly.



Clearly, with these types of changes the traditional role of students in high schools must also change. Educator Paulo Freire describes a traditional high school education with a banking metaphor. Teachers make a "deposit" into the minds of students, only to ask for "withdrawals" on tests and assignments. It is becoming less and less possible for students to know all there is to know about a topic or field, especially in the sciences. This means shifting the focus in teaching from the mastery of content toward developing abilities to access content and know how to use this content once found. This will require redefining *what* is taught and the *act of teaching*. The explicit teaching of thinking skills is one part of redefining what it means to teach science. The following table presents some of the shifts in teaching that are needed in this information era and how these shifts relate to encouraging the development of students' thinking skill abilities:

Changing Role of the Teacher in the Information Era

from . . . Directing thinking	*to* . . . Facilitating thinking
Where the teacher is . . . • a provider of knowledge • focused on content • teaching toward the norm • assessing students on common standards	Where the teacher is . . . • a mediator and collaborator in student construction of knowledge • focused on the processing of a broad spectrum of information • accommodating learner differences • assessing students individually

Changing Role of the Student in the Information Era

from . . . Being a reproductive thinker	*to* . . . Being an autonomous thinker
Where the student is . . . ● reproducing given knowledge ● seen as a passive recipient in learning ● rule-abiding, convergent in behaviour ● focused on narrow content ● expected to find the one right answer ● to view mistakes as flaws ● evaluated externally ● individualistic and competitive	Where the student is . . . ● creating and discovering knowledge ● an active decision maker ● divergent, able to step outside of rules to create original ideas ● interrelating from a wide content base ● able to find multiple solutions ● able to use mistakes as a learning tool ● evaluating himself or herself, finding self-direction ● collaborative

3. A humane society requires thoughtful thinkers

Every social institution is prone to fads; immensely popular ideas which ultimately seem destined to contribute little. Currently, there are many seminars and books on the development of students' thinking skills, to the extent that this could be considered one of the current fads in education. All the seminars and books in the thinking skills fad have one thing in common. The development of thinking skills is presented almost thoughtlessly as a simple technical or manipulative task requiring only a few lessons or steps. These programs seem to miss an important part of encouraging students' thinking abilities: *The goal of thinking.* Einstein expressed the problem well: "The world that we have made as a result of the level of thinking we have done thus far, creates problems we cannot solve at the same level at which we created them". It is therefore important to ponder not only *how* students could be improving their thinking abilities, but *why.*

If a sense of critique is not the focus of education, students could graduate from schools without understanding the moral responsibilities that are a key part of acquiring knowledge.

To be educated means more than being able to process information. What is also required is a sense of moral responsibility that comes with learning. I call this having a *sense of critique.* According to John Dewey, the ability to become an informed citizen, able to make thoughtful decisions, is *the* goal of education. If a sense of critique is not the focus of education, students could graduate from schools without understanding the moral responsibilities that are a key part of acquiring knowledge. In *Teacher and Child,* Haim Ginott makes this point in a powerful way:

On the first day of the new school year, all the teachers in one private school received the following note from their principal.

Dear Teacher:

I am a survivor of a concentration camp. My eyes saw what no man should witness: Gas chambers built by *learned* engineers. Children poisoned by *educated* physicians. Infants killed by *trained* nurses. Women and babies shot and burned by *high school* and *college* graduates. So, I am suspicious of education. My request is: Help your children become human. Your efforts must never produce learned monsters, skilled psychopaths, educated Eichmanns.

Reading, writing, arithmetic are important only if they serve to make our children more humane.

To prepare students for a lifetime of learning and the ability to examine their own knowledge critically, students will need to be sharply aware of their own thinking skills and able to grow in thinking skill abilities.

Teachers play a key role in helping children become humane. In his essay "Teachers as Transformative Intellectuals", Henry Giroux reminds teachers that they are intellectuals who have a major role in "educating students to be active, critical citizens." How can teachers do this? Giroux suggests three ways:

- by examining with students the political nature of schooling
- by acknowledging that students are critical thinkers capable of helping society to change
- by developing with students, parents, and the community a sense of critique.

The active teaching of thinking skills with a goal toward developing a sense of critique will result, claims Giroux, in "the conditions that give students the opportunity to become citizens who have the knowledge and courage to struggle in order to make despair unconvincing and hope practical." In other words, students who will become citizens willing and able to help our society become more humane.

Is this goal possible? Yes. Reaching this goal begins with the recognition that learning is a lifelong process, which is encouraged in schools but does not end there. To prepare students for a lifetime of learning and the ability to examine their own knowledge critically, students will need to be sharply aware of their own thinking skills and able to grow in thinking skill abilities. This will require children to develop not only their thinking skills, but also their metacognition. It is a great task, but within reach. Alberta Education has proposed the following principles to increase the development of thinking skills and metacognition in the Province of Alberta:

- Students should have opportunities to improve their thinking skills.
- Students can improve their thinking skills.
- Educators should use a wide range of strategies in teaching thinking skills.
- Educators should encourage thinking skill development in the context of school subjects.
- Educators should have opportunities to learn about thinking skill development and how to teach thinking skill development.
- Educators and students should use appropriate evaluation techniques to assess thinking skill development.
- Administrators can and should ensure positive attitudes toward thinking skill development in schools.
- Alberta Education should make the teaching of thinking skill development explicit in curriculum documents.

Clearly, a major responsibility for developing the thinking skills abilities of children falls to educators. The following are some practical ways educators can encourage students' thinking skill development in the high school science program.

SOME WAYS TO ENCOURAGE THINKING SKILL DEVELOPMENT IN SCIENCE

1. **Setting the stage: Developing an atmosphere where thinking can grow**

   High school science teaching tends to follow a pattern of presentation and elaboration of a particular concept followed by an experience or activity to demonstrate the concept. Research on students' learning in science classes supports reversing this approach to science teaching by developing more inductive science classes. An inductive approach places the challenge for learning with the student; the teacher acts as a guide, or mentor, to the learning process. Learning a new concept inductively begins with concrete exploration, leads to clarification and organization of ideas, and finally abstraction and application of learning. This method of teaching provides fertile ground for students' thinking abilities to grow and flourish.

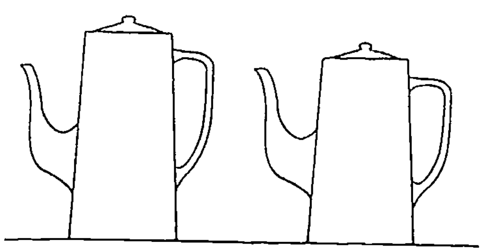
Learning a new concept inductively begins with concrete explorations. leads to clarifications and organizations of ideas. and finally abstraction and application of learning.

An inductive approach to teaching science could be considered as both an invitation and challenge to student thinking. Much depends on the teacher establishing a classroom climate that encourages students to think. Here are some suggestions to consider:

a. Creating a climate for thinking

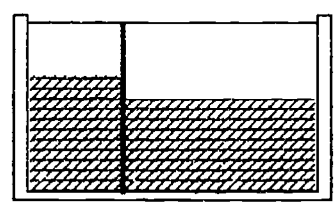
The use of bulletin boards and displays invites students to be engaged in thinking. For example, teachers could post a word or a phrase, such as "Coriolis effect" (Science 10), and challenge students to define the word, or to discover something about Coriolis. Teachers could post pictures of tornadoes with some probing questions (e.g., In which direction does a tornado turn? Does it always turn the same way? What was the worst disaster in the history of tornadoes? and so on), but students would have to find the answers themselves. Some teachers put brain teasers up to encourage student thinking, leaving answers until everyone has an opinion. For example, teachers could post the following two brain teasers:

Brain Teaser 1



These two coffee pots have the same cross-sectional area. The first is taller than the second. Which of the two (if either) will hold more coffee?

Brain Teaser 2



An aquarium has two compartments, one very small and one large, formed by a vertical membrane made of thin rubber. The water in the small compartment is at a higher level than in the larger compartment. Which way, if any, will the membrane bulge?

Wild, provocative questions such as "What would it be like to sit on the nucleus of an atom?" encourage students to think of concepts in new, creative ways.

Thinking skill development flourishes in a classroom where student ideas are accepted and encouraged, no matter how outrageous the ideas may be. By welcoming all student ideas, theories and hypotheses students will be stimulated to think critically, creatively and reflectively.

b. Teacher questioning

Teacher questioning is one way to stimulate students' thinking abilities. Wild, provocative questions such as "What would it be like to sit on the nucleus of an atom?" encourage students to think of concepts in new, creative ways. Science teachers often stimulate students to think critically by playing "Devil's advocate"; for example, one teacher argued with a class that a rock rolling down a hill is alive. Students then argued until they convinced the teacher the rock couldn't be alive. In this way the teacher and the students developed a definition of life.

c. Metacognitive sharing

One very important way teachers can encourage the thinking abilities of their students is to make explicit their own thinking processes. By sharing their own metacognition, teachers are making thinking skills prominent and valued in the classroom and are helping emerging adults discover how adults think and approach the world.

d. The science course organization and focus

Students typically do not make connections between science topics or subjects.

Research indicates that the organization and focus of a science course has a major role in stimulating the development of students' thinking abilities. Students typically do not make connections between science topics or subjects. When science is presented as an integrated course of studies with themes that transcend discipline boundaries the critical-thinking abilities of students seem to be encouraged. A discussion of how teachers can emphasize some of the major themes in science appears in this teacher resource manual.

e. The role of students

High school students must begin to see themselves as partners in learning, willing to raise questions and work with peers.

Students also have to change their approach to education if their thinking skills are to be encouraged. High school students must begin to see themselves as partners in learning, willing to raise questions and work with peers. Students will need encouragement to learn from each other in a cooperative, rather than competitive, way. Through group work, teachers can begin to open opportunities for students to learn to work together at learning.

Students will also need to apply their thinking skills in a practical way. Thinking always involves *thinking about something.* For example, one science class decided their school should be recycling paper waste. The teacher then put the onus on the students to do something about their concerns. The result was a school-based recycling project which, to date, has been very successful. In this case, the role of the teacher was not to disseminate knowledge, but to facilitate a process which required students to think critically, creatively and reflectively about paper wastes in their school, and then to act on their thoughts.

2. Planning for the Teaching of Thinking

Through explicit planning, teachers can encourage the development of students' thinking abilities. One way to do this is to use a "thinking skill planning chart" which relates the topic or concept being taught to the three domains of thinking. Various activities that stimulate thinking could then be used in the lesson. Thinking activities have a wide range of applications. For example, concept mapping could be used to explore critically the connections in a concept, or to discover creative ways of linking information, or to reflect on an idea. Choosing thinking activities is a creative act. Since activities are chosen to develop a particular aspect of a topic, teachers will likely choose different activities for the same concept. The following example illustrates how teachers might plan activities to promote thinking skill abilities within the context of a particular concept or topic:

Planning Thinking Skill Activities

Science Concept Or topic	Thinking Skill Activity	Critical Thinking Emphasis	Creative Thinking Emphasis	Reflective Thinking Emphasis
circulation of the blood in the human body	concept mapping	look for alternative conceptions, gaps in knowledge, or learning progress	discover alternative perspectives for viewing circulation — when would this be valuable?	What if we had two hearts? Why does the heart refer to love? Is this so in other languages?

3. Activities

The following list of techniques enhances the development of critical, creative and reflective thinking skills at various levels in the process of learning. This list is not exhaustive, but suggestive of how teachers might approach, in practical ways, teaching thinking in science. Teachers may also wish to refer to *Teaching Thinking*, *Enhancing Learning*, published by Alberta Education, for more ideas on thinking skill activities. This document contains an extensive reference list and thinking skill evaluation ideas for teachers interested in learning more about the development of students' thinking skills.

The thinking skill activities that follow are grouped into three stages: beginning, organizing information and using information. This organization parallels how a topic in science should be developed, from the concrete exploration stage (Stage 1 – Beginning Exploring, Gathering, Focusing) to an organizing of information stage (Stage 2 – Organizing Information/Developing Categories/Concepts and Ideas), and finally to abstraction and application (Stage 3 – Using Concepts and Information, Being Thoughtful Thinkers). In each stage are several types of activities and related methods teachers can use to encourage the development of student thinking skills.

Stage 1
Beginning Exploring, Gathering, Focusing

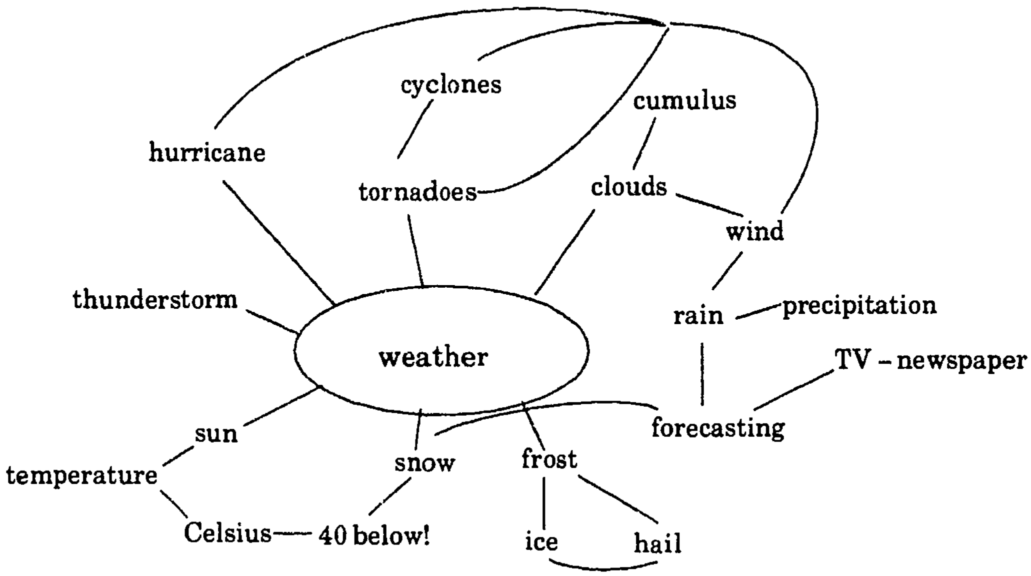
a. Brainstorming involves . . .

Producing a flow of ideas; generating many ideas on a topic. Connections can be discussed; creativity is enhanced much as possible. Judgments on ideas gathered and generated should be held in reserve as much as possible.

Methods:

Spidergrams

Place a concept, word, picture at the centre of a page. Draw lines radiating from the centre. What results is a web of words, phrases, pictures resembling a spider's web. Post the results; identify themes, common ideas, differences.



List making, sharing lists, word associations

Place a word, phrase or picture at the top of a piece of paper. A student writes the first thing that occurs to him or her, then passes the list along. After the list has been added to by all students it can be collected and analyzed, or posted, etc.

Photo collages

Search through old magazines looking for pictures that reflect an idea, theme or word. Cut the pictures out and arrange them in a way that makes sense. This is a good group activity.

Search and scan

Quickly scan through a lot of print material (newspapers work the best) to see what themes, words, etc., emerge. What does this say about the print source? About the use of words? Other probing questions can be developed, or this exercise can be used simply to discover the frequency of ideas, themes, and so on, in print.

Labs involving counting, sampling

These are useful in gathering a lot of data quickly. Field studies in biology, many trials of a single experiment in physics or chemistry help students to see the importance of replication and the role of uncertainty in research.

b. Elaborating involves . . .

Extending, embellishing, adding to a set of ideas, probing deeply into meaning to find new insights, adding detail, becoming informed.

Methods:

Probing words, symbols, illustrations

Students tend to have a limited understanding of the history behind science words, discoveries or ideas. Challenge them to research the meaning behind symbols; e.g., KPa: Who was Pascal? What does kilo mean? Why was this word used?

> *"A White Elephant"*
>
> *The kings of Siam gave white elephants to any courtiers who seriously annoyed them. Although the animals were held in high esteem, and regarded as sacred, their upkeep was so costly that anyone who received one was apt to be ruined!*

Making of models

Helps to make ideas concrete. Students can prepare paper models of protein synthesis, molecular arrangements in a crystal, plant cells, or design graphic representations of a science event, such as electron transfer between atoms (oranges work well as electrons, so do Lifesavers), mitosis in a cell, or the acceleration of a falling object. Students should be challenged to say how the model fits the evidence, and comment on the weaknesses of the model.

"Even though many people saw the skeletons, a brontosaurus never existed . . ."

Vague to specific writing

Give students something vague enough for them to explore further. For example, the phrase "Even though many people saw the skeletons, a brontosaurus never existed . . ." begs to be researched further. This type of prompting brings out the detective in students.

c. Evaluating involves . . .

Determining criteria for evaluation, assessing information for accuracy, probing assumptions, presenting an opinion.

Methods:

PMI

This involves classifying a presentation, video, text, etc., by reactions "plus", "minus", and "interesting". The results should be shared, as well as why the classification was made. A PMI chart for teacher photocopying can be found at the end of this section.

Survey, gather and present information

Could involve door-to-door survey, in-school studies (number of lights left on during a day; what students tend to throw away at lunch, etc.). Students could do a survey of cell types through lab work, and then present their findings or gather information on all the physiological diseases of the cardiovascular system.

Design and use a rating scale

This could be for assessing students' own work, lab skills, etc. Scales could be numerical (1 to 5), graphic (like a thermometer on "how I feel about an issue", or a dial representing school spirit), or any other means of rating something. This exercise encourages creativity.

Design and use a criteria assessment

For assessing the strength of an argument, hidden assumptions in a presentation, develop a criterion for determining if an experiment was successful.

Stage 2
Organizing Information/
Developing Categories/
Concepts and Ideas

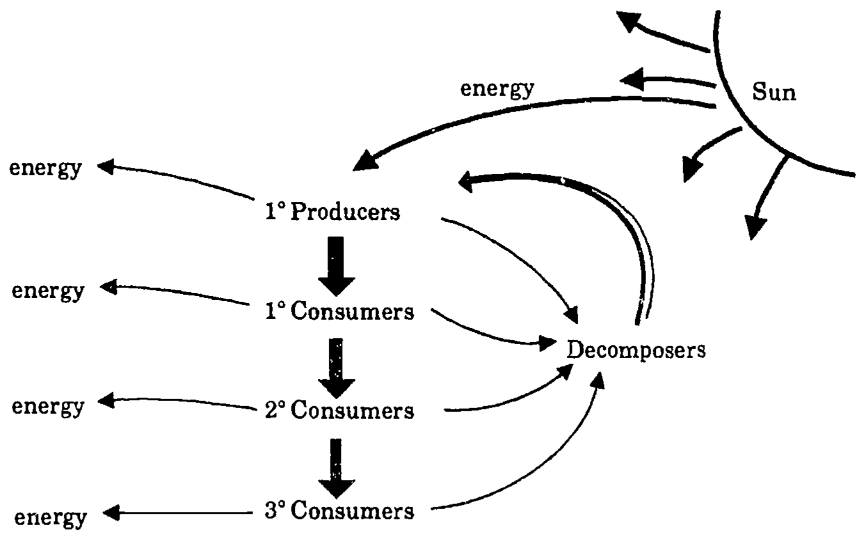
a. Pattern making involves . . .

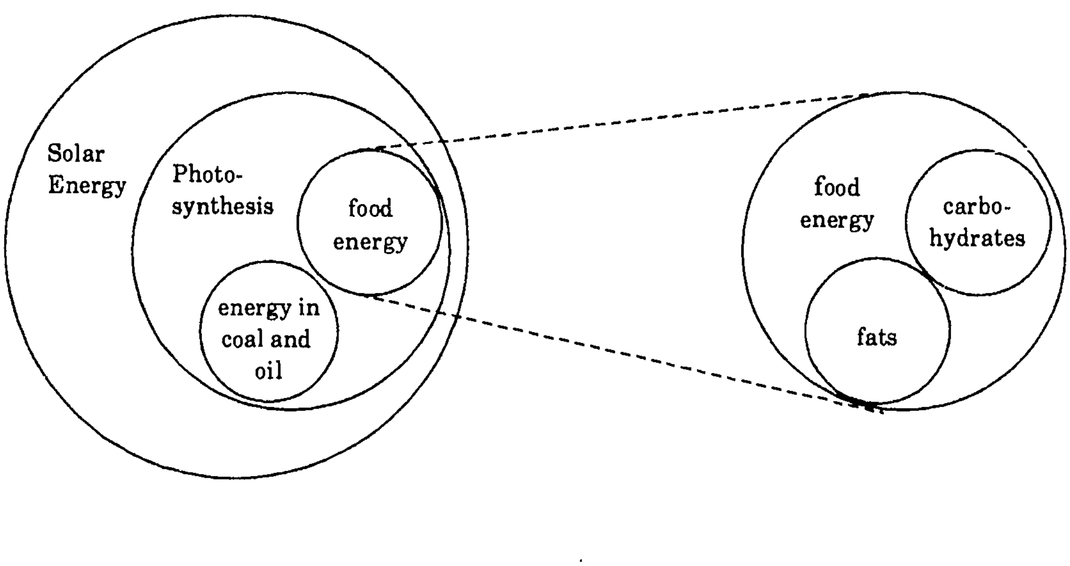
Making associations and connections, organizing information, new ways of looking at information, recognizing patterns and trends, deductive thinking.

Methods:

<u>Concept maps and concept circles</u>

These are valuable concept organizers. They demonstrate student learning and where "alternative" ideas and misconceptions may exist. Concepts should be clearly labelled and *the relationships explained by the students*. Some examples of concept maps and concepts circles are given:





Five possible concept map ideas from Science 10:

- Compare the organelles in a cell to organs in the human body (basis of comparison is up to the group).
- Trace the flow of energy through the biosphere.
- Compare the transportation system in an *Amoeba* to that of a giraffe.
- Relate changes in energy to changes in motion, shape, and temperature of matter.
- Compare the separation techniques of filtration, distillation, extraction and chromatography.

Sequence maps

Show the relationship of one idea to another; e.g., the stages of mitosis, the steps in naming a compound, cause-and-effect relationships. One very effective sequence map is to develop a "history" chart. Each student is assigned a decade and must, on a 8½"×11"inch piece of paper, write the major scientific developments and social/political events of the decade. Students then post their charts in the room, resulting in a broad sweep of the history of science together with a feeling of how science is related to social change.

Flow charts

Adaptable to many situations, such as classifying or identifying chemical compounds, classifying an organism, deductive problem shooting (for example, determining what's wrong with a car that won't start).

Graphing

Presenting information gathered in a graphic format encourages thinking skills; pie graphs, bar graphs, three-dimensional graphs are all useful. Learning to extrapolate from a graph, and recognition of the dangers and assumptions in doing this, is one way to encourage critical-thinking skills.

b. Synthesizing involves . . .

Combining ideas and concepts in new ways. The emphasis is on extending prior knowledge to forming a hypothesis, invention, idea or new perspective.

Methods:

Fantasy fact

This involves stating a fact (DNA exists) and then adding a fantasy (it came from outer space). Students then debate the reasonableness of the connection. This method is similar to Socratic teaching, and very effective in generating critical and creative thinking.

What if the ice cap on Antarctica were to melt?

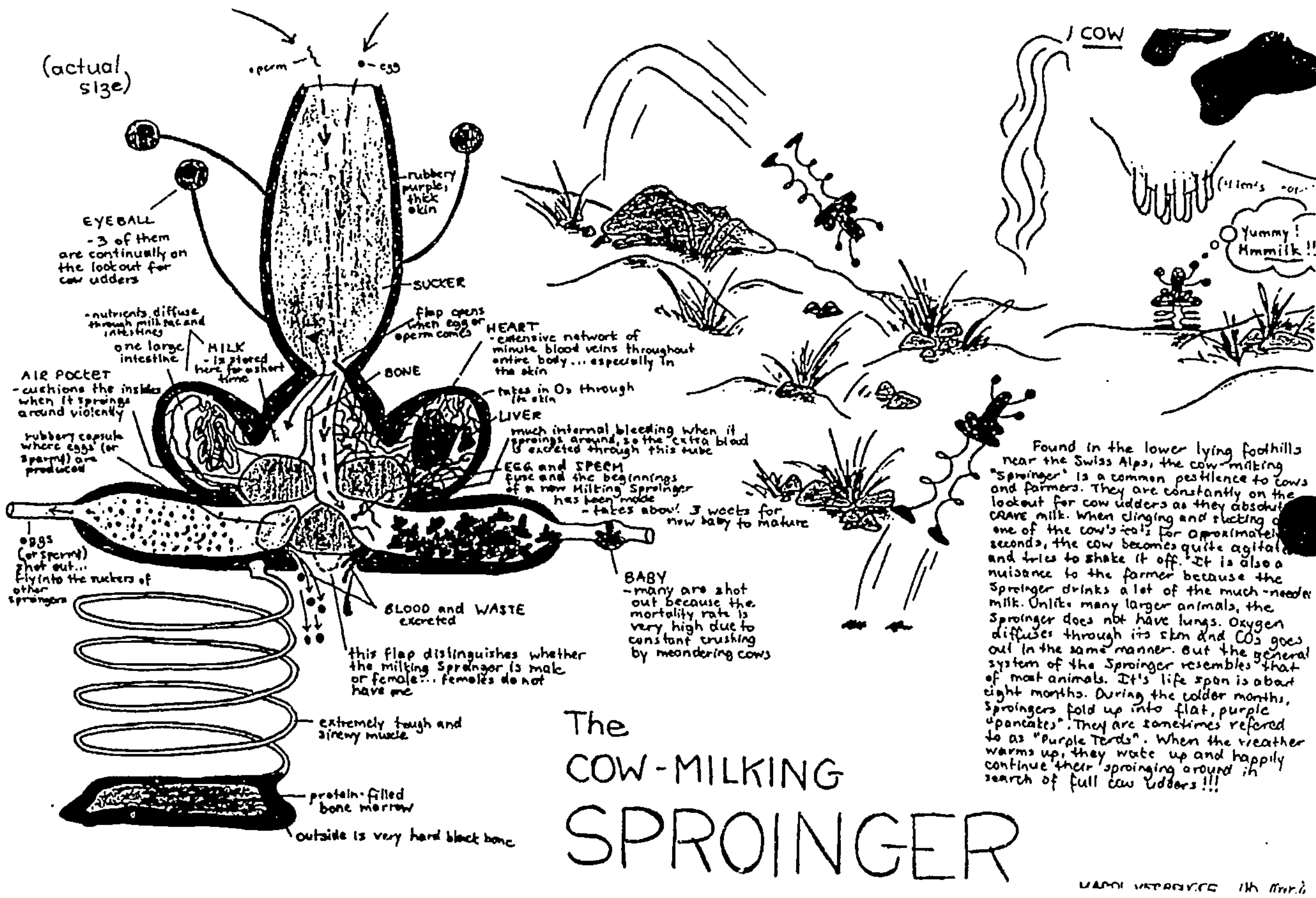
Hypothetical situations

These challenge students to think about unusual situations, encouraging them to bring concepts together. Some examples might be:

- What if the ice cap on Antarctica were to melt?
- Suppose you were to shrink small enough to sit on the nucleus of a Boron atom. What would it look like?
- Suppose we could no longer use "zero" in mathematics — how would this affect science?
- What if, for five minutes each month, people could turn into their favourite plant or vegetable?
- Suppose everyone had a set limit on the number of words they could utter in their lifetime? Would we become more precise? Would we find other ways to express ourselves? Would telepathy develop?
- What if our solar system is really a single atom, with the Sun the nucleus. What would we be then?
- Would fluorescent dyes be a good additive to dog food?

Designing something new

This can be very effective in encouraging creativity. Students could design a new way to travel, a perpetual motion machine, a new animal (including naming it!), or even a different way to learn science! The following is a sample of a Grade 11 student's design for a new animal:



Analogies and metaphors

Scientists frequently use metaphors and analogies to express difficult concepts. For example, Rutherford's "solar system" view of the atom, or the phrase "daughter cells" in biology are useful metaphors that describe something in familiar terms. Analogies compare ideas; for example, "Learning to be a scientist is like a child learning to walk". Examining analogies and metaphors encourages critical thinking; learning to generate metaphors and analogies encourages creativity and reflective thinking.

a. Predicting involves . . .

Understanding cause and effect, making forecasts based on synthesis of ideas.

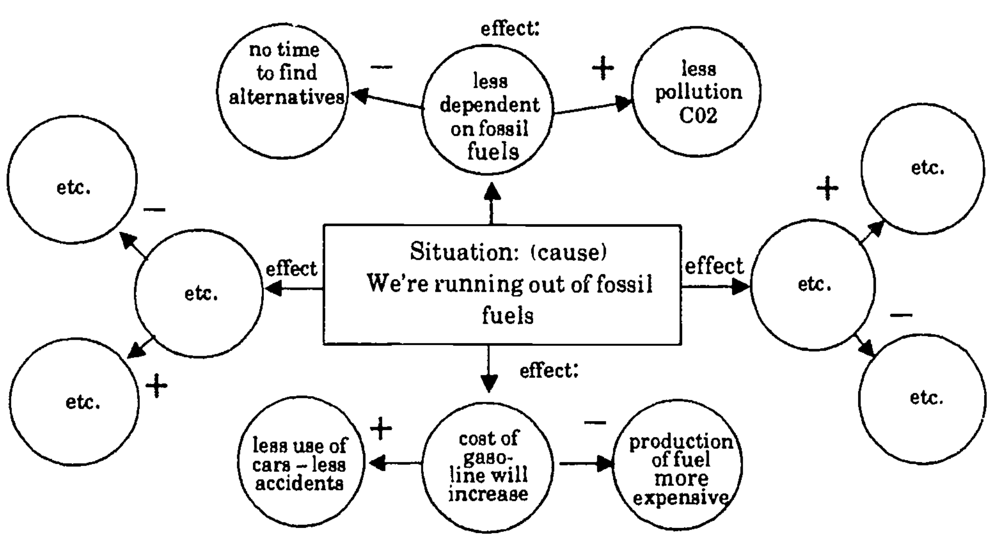
Methods:

Design an experiment to investigate a hypothesis

For example, teachers could pose a research question: Do spiders build the same pattern of webs every day? One way of researching this is to spray paint lightly onto a spider's web (being very careful not to spray the spider!) and then place a piece of paper up to the web. The result is an impression of the web. This could be conducted on alternate days and, thus, students would be researching a hypothesis.

Cause-and-effect, plus/minus charts

Similar to pattern making, this exercise looks for deliberate connections and consequences. For example, a teacher could advance the statement "War is a consequence of overpopulation!" and students could develop a cause-effect chart illustrating the plus/minus aspects of this position. This is very useful in examining the hidden assumptions of an argument and for discussing controversial issues. Following is one example of how a plus/minus, cause-and-effect chart might look:



It is especially important to follow forecasting with decision making that leads to action, and to encourage students to understand the limits and dangers of forecasts.

Problem resolving begins with the confession that we often cannot "solve" problems, but by exploration, conversation, and decision on a course of action we can make progress with a problem.

Forecast the likelihood of situations

This is highly dependent on previous thinking skills development, such as graphing and extrapolating. Students will need a lot of information to develop informed forecasts. Forecasts can be depressing for students. It is especially important to follow forecasting with decision making that leads to action, and to encourage students to understand the limits and dangers of forecasts.

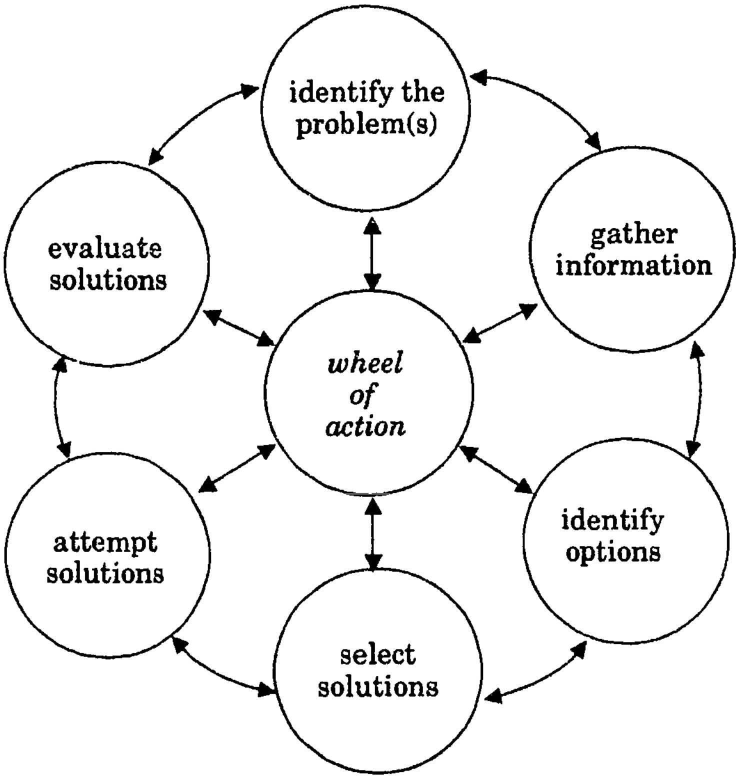
Example: What is the likelihood of:

- massive famine, given the present rise of population?
- landfill sites becoming obsolete if all the residents of a city recycled their wastes?
- an epidemic of skin cancer, if the ozone layer disappears?
- a colony on the moon by the year 2050?
- personal robots as companions for every person?

b. Problem resolving, decision making

Typically, problem solving is seen as a linear, or at best, circular process which follows a definite sequence of steps. The deficiency in this model is revealed when confronting a problem in science: often, problems seem more "messy" than a typical approach to problem solving would admit. One way to look at problem solving is to see it as "problem resolving", where the struggle with a problem involves a dynamic movement between actions. Problem resolving begins with the confession that we often cannot "solve" problems, but by exploration, conversation, and decision on a course of action we can make progress with a problem. It is natural to return to the problem anew as insights grow; this "returning" is problem resolving. Following is a model of problem resolving.

An Interactive Model of Problem Resolving



In problem resolving, the teacher's role is mainly that of a supervisor, mentor or guide to the process. Students should have the thinking skills to tackle the problem. Some ways teachers can encourage the process:

- look for reasoning errors. ("You might want to consider...")
- encourage solid understanding of issues and concepts
- help students to maintain a "spirit of critique" during problem resolving.

Students should realize there are no easy answers.

In addition to the steps on the "wheel of action", students should:

- recognize valid assumptions
- search for unstated or hidden assumptions
- discuss points of view.

Problem resolving requires practice. Students should have the opportunity to practise resolving a variety of problems, from simple to complex. The following are three sample problems which could be resolved:

Sample Problems to Resolve
1. The National Anti-smokers Protection League has successfully petitioned its local M.P. regarding the unfair practice of non-smokers having to share equal responsibility for health costs in their province. In their view, smokers should pay higher health cost premiums, or government-subsidized health care should be extended only to non-smokers and others who have a "healthy lifestyle". a. What ethical issues are raised by this group's claims? b. What if such a law were passed: who would determine what a "healthy lifestyle" is?
2. In a large research centre, white rabbits are used to test the possible carcinogenic effects of eye shadow and other "around the facial area" forms of cosmetics. To test for possible toxic reactions, the animals must be restrained and then the cosmetic being tested is applied to the animals, lips, eyes, etc. After a period of time, the animals are destroyed to check for tumours and other evidences of toxicity. The factories claim that it's better to use rabbits to reveal a problem than not to test the cosmetic at all. Also, they add, the rabbits are bred for this purpose and using animals for experimentation is no different than raising animals, such as cows, for food. a. Is the use of animals in this fashion ethical? b. What other ways could these cosmetics be tested? c. Is the consumer of cosmetics involved in this ethical issue?
3. At Stanford University, an "artificial womb" has been developed which enables researchers to study aborted fetuses (it is called a "fetal incubator"). This tool is extremely complex, and helps scientists at the university study fetuses from spontaneous (natural) abortions for up to 48 hours. The technology that prolongs the life of the fetus is used to help scientists and doctors gain knowledge about fetal responses to drugs, stimulations, etc., that could not be obtained otherwise. Researchers point out that this technology could be developed into an "artificial womb" which might be able to carry babies, born prematurely, to full term, although researchers concede this technology is a long way from being ready. a. Should researchers continue to develop this technology?

Problem Solving in Science: Elaboration of Steps

Identify the problem(s)	• identify the purpose of investigation • clearly state the problem, question or issue to be investigated • differentiate between relevant and irrelevant data or information • assemble and record pertinent and relevant background information • identify all variables and controls • identify suitable materials and apparatus required • formulate questions, hypotheses and/or predictions to guide research • design and/or describe a plan for research or to solve the problems • prepare required observation charts or diagrams.
Gathering information	• carry out and modify the procedure if necessary • organize and correctly use apparatus and materials • gather information or data in accordance with safety regulations and environmental considerations • accurately observe and record relevant data • organize and present data in a concise and effective form (themes, groups, tables, draw graphs, flow charts and Venn diagrams) • communicate data more effectively by use of mathematical calculations where necessary • demonstrate an understanding of error and where applicable calculate percentage error.
Identifying options	• analyze data and information for trends, patterns, relationships, reliability and accuracy • identify and discuss sources of error and their effect on results obtained • analyze data and information, using appropriate technology • identify attributes, claims, assumptions or reasons • identify main ideas • detect bias.
Selecting solutions Attempting solutions	• predict from the data or information • formulate further testable hypotheses supported by the knowledge and understanding generated • identify further problems or issues to be investigated • identify alternatives for consideration • propose and explain interpretations or conclusions • develop theoretical explanations • summarize and communicate findings • relate the data to laws, principles, models or theories identified in background information • answer the problem investigated • make a decision.
Evaluating solutions	• consider consequences and perspectives • identify limitations of the data, and information, interpretations or conclusions as a result of the experimental/research/project/design, processes or methods used • suggest alternatives and consider improvements to experimental technique and design • establish criteria to judge data or information • evaluate and assess ideas, information and alternatives.

Thinking Skills Planning Chart

Lesson Concept or Topic	Thinking Skill Technique	Critical Thinking	Creative Thinking	Reflective Thinking

Plus/Minus/Interesting Inventory

ISSUE:

Plus	Minus	Interesting

Summary:

REFERENCES

Ginott, Haim G. *Teacher and Child.* New York: Macmillan, 1972.

Giroux, Henry A. "Teachers as Transformative Intellectuals." *Social Education* 49 (5): 376–379.

TEACHING FOR CONCEPTUAL CHANGE

by Dr. Heidi Kass, University of Alberta

Ascertain what the learner knows, and teach accordingly.
(David Ausubel)

Scientists and children have much in common. Both try to make sense of the world and their experience with its objects and events. In this respect teachers are teaching science whenever they help their students to ask useful questions, to investigate phenomena, to explore ideas, to develop sensible and useful explanations, and to be interested in the explanations of others and in how such explanations have been developed. Often students have ideas about the phenomena studied in science courses, which are developed through their own experiences and from what other people say. These ideas and explanations may be quite different from the scientific ones. The teacher's task is to decide how to introduce the currently accepted scientific perspective on a topic in the presence of the range of prior knowledge of students, in ways that develop their scientific understanding.

Scientists and children have much in common. Both try to make sense of the world and their experience with its objects and events.

A significant amount of research carried out over the past ten to fifteen years suggests that students come to many school science learning situations with a range of personally constructed explanations or preconceptions. These interact in various ways with the scientific views and models presented in school.

The interviews that follow will illustrate the kinds of alternative views held by three academically capable students on the topic of boiling water.[1]

Elementary level student (Grade 5)	Junior High level student (Grade 9)	High School level student (Grade 11, taking Chemistry 20 and Physics 20)
I: **How do you know when water boils?** A: When bubbles come up. I: **What do you think that the bubbles are?** A: Air in the water.	I: **How do you know when water boils?** A: It starts to bubble and jump around. I: **What do you think that the bubbles are?** A: Air, oxygen.	I: **How do you know when water boils?** A: When bubbles start coming up from the bottom.
(continued on next page)	(continued on next page)	(continued on next page)

1 These interviews were conducted by Harry Klann, Concordia College, and are presented here with his permission.

Elementary level student (Grade 5) (continued)	Junior High level student (Grade 9) (continued)	High School level student (Grade 11, taking Chemistry 20 and Physics 20) (continued)
I: **How do you know that these bubbles are air?** A: There has to be air in the water. I: **Why do you think so?** A: Because fish live in water and breathe the air out through their gills. I: **Why does the air leave the water?** A: Because the heat is pushing it out. I: **How long will this happen?** A: I don't know . . . usually for a few minutes. I: **Where does the air come from to keep the bubbles coming for such a long time?** A: From inside of the water.	I: **How do you know that these bubbles are air?** A: It has to be. I: **Why do you think so?** A: Because fish take it out of the water to live. I: **Why does the air leave the water?** A: When heated, molecules move apart and the air or oxygen molecules move out. I: **How long will this happen?** A: For a long time . . . as long as it keeps boiling. I: **Where does the air come from to keep the bubbles coming for such a long time?** A: Water is made up of hydrogen and oxygen and air has oxygen.	I: **What do you think that the bubbles are?** A: Oxygen and hydrogen gas. I: **Where did the oxygen and hydrogen gas come from?** A: Applying heat results in the simple decomposition of water to form its parts, hydrogen and oxygen. I: **Why do you think so?** A: Because water is made up of these two simple elements that can exist only as their molecular forms which are gases. I: **Why does the air leave the water?** A: When heated, the gases are formed and bubble off. I: **How long will this happen?** A: For as long as you keep the water boiling and until there is no more water. I: **Where do the gases come from to keep the bubbles coming for such a long time?** A: From the continuous decomposition of water till it is all gone.

The students at the three levels have the same basic idea of how to tell whether or not water is boiling. No attempt was made even by the Physics 20 student to describe boiling water from the physics perspective; i.e., water boils when its vapour pressure is equal to the atmospheric pressure. All had the idea that the bubbles were air (or oxygen and hydrogen). Yet all three indicated that they were certain that their responses were correct.

The alternative ideas held by students share some general features. Among these are:

a. Perceptually dominated thinking; e.g., sugar disappears when it dissolves.

b. Limited focus; e.g., in explaining the action of a drinking straw, many students consider only what is happening inside the straw and attribute the motion of the liquid to "suction" rather than to a difference in pressure inside and outside the straw. Another example is the idea that a force is acting only when motion is observed.

c. Linear causal reasoning. Students often have a "preferred" direction when reasoning about events; e.g., students can understand that adding energy may change a solid to a liquid but be unable to explain what happens when a liquid turns to a solid. Processes considered to be reversible by scientists may not be seen this way by students.

Some of the personally held meanings are unexpectedly different from the views of the scientific community and may be highly resistant to change.

d. Undifferentiated concepts; e.g., force, energy and momentum are used interchangeably in explanations. In general, students' notions tend to be more global and inclusive than those of scientists.

For the teacher, a number of questions may arise:

a. What experiences lead students to such responses?

b. What additional experiences might be necessary to help these students understand the scientific basis for this phenomenon?

c. What teaching strategies might help the students to revise their thinking?

Some of the personally held meanings are unexpectedly different from the views of the scientific community and may be highly resistant to change (Driver, Guesne and Tiberghien, 1985; Osborne and Freyberg, 1985). Studies in various parts of the world have shown a similar range of particular ideas about a topic, a finding consistent with the position that these alternative views are constructed by the person from direct experience with the world through everyday events. For example, personally held alternative views of force and motion are often considered by students to be more sensible and useful than those presented to them by teachers; e.g., heavy objects fall faster; if a body is not moving, there is no force acting on it. Also, terms such as "energy" and "work" have scientific meanings that are significantly different from their meanings in ordinary language. The more general everyday meanings can interfere with the scientific meaning. For example, the technical (restricted) physics meaning of the term "conservation of energy" applies only to closed systems while "conservation of energy" as talked about in everyday contexts is applicable to open systems (Osborne and Freyberg, 1985). The potential for logical mismatch and conceptual confusion can be significant, pointing to a need for teaching approaches that are adapted to dealing with the understandings that students may already have as a prerequisite to building the student's knowledge.

The potential for logical mismatch and conceptual confusion can be significant, pointing to a need for teaching approaches that are adapted to dealing with the understandings that students may already have as a prerequisite to building the student's knowledge.

A constructivist view of learning holds that new ideas can be built up through developing meaning for sensory input by using existing ideas and experience. Of necessity, the learner's prior knowledge framework plays an important part. It is often assumed that either the learner has no knowledge that can have a bearing on the topic (the "tabula-rasa" assumption) or that any ideas the student may have can be directly and easily replaced by the more correct ideas presented by the teacher (the "teacher-dominance" assumption). Researchers now recognize that the situation is more complex than suggested by these two possibilities. Gilbert, Osborne and Fensham (1982) identify five possible outcomes from science instruction that can occur, often within the same science class:

a. The undisturbed alternative perspective.

   e.g., the bubbles in boiling water are air or hydrogen and oxygen; or "the higher up you go, the stronger the gravity is until you get out of the atmosphere" (Osborne and Freyberg, p. 87).

b. The two-perspective outcome

Students may construct a "school science" viewpoint that may be different from how they really think.

   Students may construct a "school science" viewpoint that may be different from how they really think. No attempt is made to reconcile the two: one is for examination; the other for "real life". In the example on boiling, the students were certain their explanations were correct, although the Grade 9 and Grade 11 students had studied phase change.

c. The reinforced outcome.

Ideas that are taught are interpreted to support the prior idea; e.g., the idea that, upon boiling or evaporation, water changes into air is reinforced by learning that the water molecule consists of hydrogen and oxygen, and air contains oxygen.

d. The confused outcome.

Students may lose confidence in their earlier naive, but relatively coherent, ideas and be reduced to a state of confusion which negatively influences future learning; e.g., the idea that heat has one type of effect on matter, namely chemical decomposition. Such a view is inconsistent with the variety of changes that matter can undergo when energy in the form of heat is added and that what actually happens depends on the situation.

e. The unified science outcome.

If science teaching is to extend the student's understanding about the world, the ideas introduced by the teacher in science lessons must interact with the student's earlier experience, whether this be in-school or out-of-school. Discrepancies between the teacher's intentions and the learner's views can be identified and reduced by means of a constructivist teaching strategy (Erickson, 1979; Osborne and Fieyberg, 1985). By looking at what is known about specific commonly held ideas that students may bring to a topic, a change in the role of the teacher from a dispenser of information to a guide in the learner's conceptual growth can emerge.

If science teaching is to extend the student's understanding about the world, the ideas introduced by the teacher in science lessons must interact with the student's earlier experience, whether this be in-school or out-of-school.

Are there identifiable components to science lessons which try to modify students' strongly held ideas in directions more consistent with a scientific world view? The sections that follow explore a teaching model which has been proposed in order to clarify, challenge and extend student functional understandings of interrelationships among scientific ideas. The model suggests an approach that can be used by secondary school teachers to design and analyze appropriate teaching strategies.

A CONSTRUCTIVIST SCIENCE TEACHING MODEL

A well-known three-stage instructional strategy that underlies science teaching has been described as "the learning cycle" (Karplus, 1977) or "the inquiry approach". Figure 1 presents the main elements of this strategy in relation to the personally held conceptions of the learner and the process of conceptual change.

The model may be viewed as an inverted "V", with interplay and crossovers between the two sides at corresponding stages. Stage 3, the empowerment stage (or understanding stage, since understanding is empowerment in the sense that it enables the learner to act) is viewed as the apex of the "V". This stage embodies the goals or outcomes of the science teaching/learning process. Both the subject matter side and the psychological conceptual side are viewed as necessary for the development of understanding. The model itself may be viewed as recursive in that the cycle of the three stages can serve as a guide to planning units, topics, individual lessons, or lesson sequences. Transition from one stage to the next is viewed as involving the development and practice of various skills: science process skills, metacognitive skills, decision-making skills, logical-thinking skills, reflective-thinking skills, problem-solving skills, and creative-thinking skills.

Each level is now described in turn. The description is followed by a possible sequence on the theme of energy.

STAGE 3
EMPOWERMENT
(UNDERSTANDING)

ACTION PHASE

- problem–solving skills
- decision–making skills
- creative–thinking skills

STAGE 2
KNOWLEDGE BUILDING

CONCEPT INTRODUCTION PHASE

CONCEPTUAL CHANGE, RECONCEPTUALIZATION PHASE (see Fig 2)

- science process skills
- logical–reasoning skills

- metacognitive skills & strategies
- reflective–thinking skills

STAGE 1
EXPLORATION

CONCEPT EXPLORATION PHASE

IDENTIFICATION AND EXPLORATION PHASE
- alternative views

LOGIC ASPECTS OF SUBJECT MATTER

PSYCHOLOGICAL ASPECTS OF KNOWLEDGE REPRESENTATION

FACTUAL/METHODOLOGICAL SIDE (L)

PSYCHOLOGICAL/CONCEPTUAL SIDE (R)

Figure 1: Framework Underlying Constructivist Science Teaching Strategy

Stage 1 (L). Exploration

In the exploratory phase, emphasis is on developing a pool of shared experience with the phenomena and events in question. The goal is to raise questions in the minds of the students. The exploratory phase is particularly important in areas such as chemistry where students lack first-hand exposure to chemical phenomena. Science process skills are involved here, and build on proficiency developed in earlier grades. Opportunity to practise logical-reasoning skills is also stressed. While the students may be gathering a great deal of information in this stage, it is not to be confused with direct transmission of information about science on the part of the teacher.

Stage 1 (R). Identification and Exploration Phase

In a constructivist approach, exploration is also focused on bringing to view the various ideas and alternative ideas that students may have about the topic (it might be useful to make a distinction between naive ideas [preconceptions] and alternative ideas or explanations [alternative conceptions] that may have developed in earlier instruction). The goal here is similar to the subject-matter side in that ideas are identified and judgment is withheld. Questioning to elicit the ideas is a key technique. Various metacognitive strategies (metacognition is thinking about one's thinking) such as concept mapping can also be used at this stage to reveal to both the students and the teacher the specific ideas they have. Self-awareness of what one does and does not know is an important part of reflective thinking and a guide to the next stage of knowledge building for both the teacher and the student.

Stage 2 (L). Concept Introduction Phase

On the subject-matter side, the scientific content, terminology, mathematical representations, symbols, and explanatory models are introduced to deal with the questions and problems formulated in STAGE 1. This is the traditional focus of secondary school science teaching.

Mathematics is one of the languages of the imagination.
(Northrop Frye)

The introduction of mathematics ideas from geometry, algebra and trigonometry as ways of representing and thinking about scientific ideas serves an an important unifying strategy. Science involves both qualitative and quantitative reasoning and problem solving.

Stage 2 (R). Conceptual Change/Reconceptualization Phase

In constructivist science teaching, the corresponding psychological side now focuses on restructuring the student's existing explanatory frameworks in a meaningful way. The teacher cannot do this for the student — the teacher can set the stage and design activities that, if successful, will enable the student to do this for herself/himself.

Figure 2 presents a flow chart of a conceptual change teaching strategy.

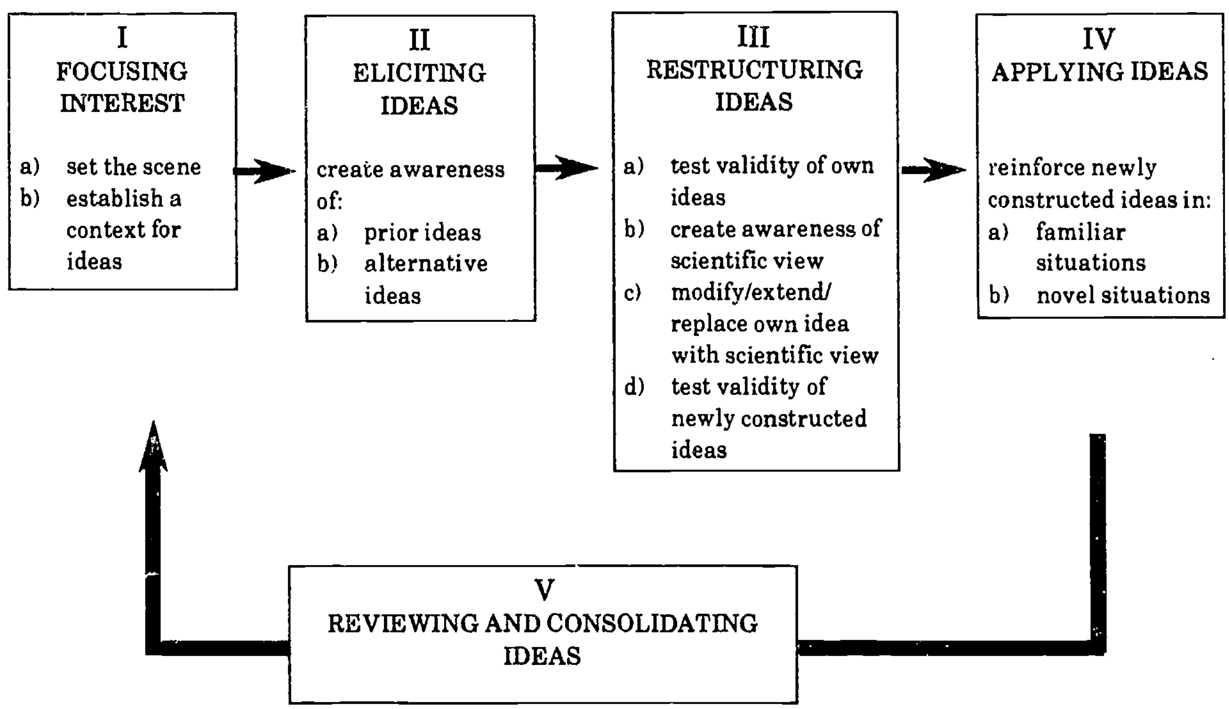


Figure 2. Teaching for Conceptual Change

Energy: Chemical Change and Physical Change

Framework		Example	
Factual Methodological	Psychological Conceptual	Factual Methodological	Psychological Conceptual
Stage 1 develop experience with phenomena, design activities to raise questions	identify prior views and range of alternative views – differentiate energy from other ideas; e.g., force	demonstrate several phenomena on forms of energy; e.g., burning splint, creation of a precipitate, conductivity of a solution, expansion of a gas or liquid, phase change, growth. Ask students to predict the outcome, then observe outcome and explain.	spontaneously propose or list a range of commonsense ideas about energy, its forms, transformations and effects – organize key words into a concept map according to perceived interrelationships (see appendix for example)
Stage 2 introduce content and terminology, symbols, formulas, models, representations, and theories	select from sequence in Figure 2	physical and chemical change, potential energy, chemical potential energy, exothermic and endothermic reactions, change of state, kinetic energy, molecular motion, KMT, closed and open systems, the measurement of energy.	test each common-sense idea and keep track of outcome – redesign concept map at regular intervals – identify unanswered questions.
Stage 3 consolidation, extension, application of ideas, evaluation of what is known and where additional knowledge is needed	practice and more practice! – practice using new ideas in broad range quantitative and qualitative situations – evaluate the usefulness of the scientific definition of energy	create a structure of interrelationships among the ideas. Which are the key ideas? – journal writing on issues – Earth as one energy system	relate "conservation of energy" in the everyday sense to conservation of energy in the physics sense. What happens to the idea of conservation in the chemical and biological domains?

Some degree of conceptual conflict (generated by the teacher or by the students themselves) seems to be necessary in encouraging students to recognize that their existing views may require modification. However, the mere existence of a perceived discrepancy or sl ortcoming is not enough. Posner et al. (1982) have identified three criteria that a new idea needs to meet in order for conceptual change to occur. The new idea must be:

a. intelligible -- the learner has to understand the substance of the new idea; i.e., what the idea is about. If the context and language of the new idea are not grasped, any of the other four aforementioned outcomes of instruction may emerge and conceptual growth is not achieved.

b. plausible -- the learner needs to be intellectually satisfied that the new idea "makes sense" and is supported by the evidence.

c. fruitful — the learner perceives the pay-off or advantage of the new idea in clearing up problems in the existing viewpoint or in making better predictions/explanations based on the evidence.

Some degree of conceptual conflict seems to be necessary in encouraging students to recognize that their existing views may require modification.

Various specific teaching techniques and pupil activities can be used in the phases of the conceptual change strategy. The teacher may:

- ascertain student views with class activities; e.g., a predict–observe–explain sequence
- classify, interpret and clarify student views to themselves and for each other
- establish specific contexts and provide motivating experiences such as discrepant events
- present the evidence for the scientific view
- stimulate discussion on the merits of various solutions or approaches
- identify historical views; evaluate evidence that led to changes
- encourage students to present their own views to the class in a climate of mutual respect and to test their views by seeking evidence.

Transition from STAGE 2 to STAGE 3 provides the student with practice in using problem-solving skills in both familiar and novel situations, in opportunities for creative thinking and experience in selection among alternative courses of action. These types of skills lend themselves to activities directed at technological problem solving and study of STS issues as well as to the consolidation of the scientific ideas and quantitative problem-solving skills. The key here is practice and more practice with the scientific ideas until the student is comfortable with them in a variety of contexts and develops a sense of his/her own growth in conceptual understanding.

The challenge for teachers is to generate an instructional strategy that helps students turn scientific information into personal knowledge while at the same time retaining an inner tension between imagination and evaluation; between the speculative and the factual.

Teaching science is a complex and at times volatile activity which demands skills and professional expertise that go well beyond knowledge of subject matter. There is a need to develop and agree upon a language of professional discourse to express research findings and ideas about how to develop understanding on the part of the science learner. Some things can only be communicated by example, and perhaps some things can only be understood by experiencing them. For example, the meaning of an STS issue is one that may require the experience of certain types of group work or action for the students to come to an understanding of what makes an issue an issue. The theme of energy conservation lends itself well to a number of activities that integrate the scientific ideas with everyday experiences.

The challenge for teachers is to generate an instructional strategy that helps students turn scientific information into personal knowledge while at the same time retaining an inner tension between imagination and evaluation; between the speculative and the factual. Such an interplay acts as an impetus to conceptual growth.

REFERENCES

Driver, R., Guesne, E., and A. Tiberghien 1985. *Children's Ideas in Science.* Milton Keynes, England: Open University Press.

Erickson, G. 1979. "Children's Conceptions of Heat and Temperature." *Science Education* 63:221–230.

Gilbert, J.K., Osborne, R.H., and P.J. Fensham. 1982. "Children's Science and Its Consequences for Teaching." *Science Education* 66:623–633.

Karplus R. 1977. *Science Teaching and the Development of Reasoning.* Berkeley, CA: University of California.

Mason, C. L. 1992. "Concept Mapping: A Tool to Develop Reflective Science Instruction". *Science Education* 76:51–63.

Osborne, R., and P. Freyberg. 1985. *Learning in Science.* Auckland, N.Z.: Heinemann.

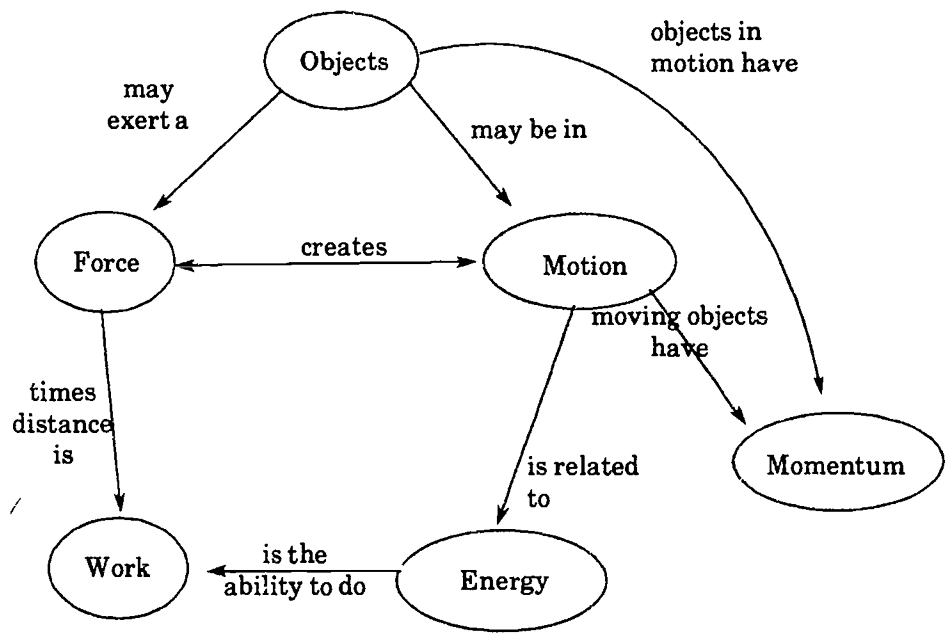
Posner, G.J., et al. (1982). "Accommodation of a Scientific Conception: Toward a Theory of Conceptual Change." *Science Education* 66:211–227.

APPENDIX
The Use of Concept Map

Concept maps are diagrams that show how people perceive relationships among concepts. They are a powerful diagnostic tool for revealing student beliefs. Concept maps can be used early in a teaching strategy to probe the ideas that students bring to a topic, or later in the instructional sequence to monitor conceptual change. Missing links can also point to weaknesses in the structuring of the content of the course.

Concept maps can be used early in a teaching strategy to probe the ideas that students bring to a topic, or later in the instructional sequence to monitor conceptual change.

The terms in a concept map can be concepts, events, objects, laws, themes, characters, classroom activities or any other set of <u>interrelated</u> items. One set of items, presented separately on small pieces of paper, are arranged on a page and the student considers each item with ALL the others in turn. Those that are related in any way are linked with a line and the nature of the link is written on the line. One example below illustrates possible linkages in the area of force, motion and energy:



Note that in the above example some ideas are clearly linked while other relationships, notably among the concepts of energy, momentum and work, are perceived in a superficial way. Some review or additional work in strengthening these connections may be indicated.

When introducing students to the strategy of concept mapping, it is useful to begin with a familiar topic in which the links are definitional, such as the example above, or atoms, elements, etc. Use four to six concepts in the early concept maps, working up to seven to ten concepts in later tasks. Require students to organize their own layout of concepts and stress that there is no one correct answer. As students acquire skill in concept mapping, they can be asked to identify concepts that are significant to them and to draw concept maps linking these.

Concept maps are a powerful way of stimulating thinking and are an excellent stimulus for small group or whole class discussion. Do not overuse the technique, and vary the context in which it is used, in order to maximize its effectiveness in stimulating reflective thinking on the part of students.

TEACHER AS FACILITATOR

by Dr. Audrey Chastko, University of Calgary

Earlier this term I attended several meetings of senior high school science teachers. A major concern of teachers at these meetings centred around their inservice needs in preparing themselves to implement the new Science 10 curriculum for Alberta schools. I was, and still am, struck by the level of anxiety that the prospect of teaching this new course seems to generate among this group of well-qualified, highly respected, and successful science teachers. They communicate a sense of uncertainty about their abilities to deal with the course and a need to learn, or relearn, how to teach school science. As one teacher attending one of these meetings put it, "We only know chalk and talk. We need to learn different teaching strategies to teach this new course."

Yes, the Science 10 curriculum looks, and probably will feel, quite different from the science curriculum we have been teaching in Alberta over the past several years. But change in the school curriculum is not a new phenomenon. All school curricula continually undergo review, revision, and change. The school science curriculum is no exception. Indeed, many of these same science teachers have successfully and confidently dealt with changes in the science curriculum as part of the normal course of events in their teaching careers. What is it about this curriculum revision that makes successful teachers question their abilities and preparation to teach the Science 10 course?

The new curriculum sees the science teacher as a facilitator of the learning of science rather than the expert/lecturer or dispenser of scientific knowledge.

Clearly, this curriculum revision goes beyond merely tinkering with the minor details of the scope and sequence for courses in school science. On the one hand, it asks us to link several scientific disciplines within one course of studies. On the other, it specifies the development of scientific literacy as a major goal for the course. I doubt that many science teachers would argue with my colleague who expressed the need to explore the potential of different, perhaps new, teaching strategies in implementing the Science 10 course. Nevertheless, while exploration of new or different teaching strategies identifies a practical concern for many experienced teachers, it makes probably the most important implication of this curriculum revision.

This implication is a change in the view of the role of the science teacher from what we have come to regard as appropriate in present practice. In short, the new curriculum, I think, sees the science teacher as a facilitator of the learning of science rather than the expert/lecturer or dispenser of scientific knowledge. Moreover, since it is often difficult to learn how to do something differently without first examining why we should be doing it differently in the first place, it seems important to begin dealing with this role at the outset. The major purpose of this paper then is to explore the role of the teacher as facilitator in the science classroom, and its implications for change in classroom practice. Let us begin by examining present practice in relation to the new science curriculum.

Some current research in science education provides us with in-depth studies of prevalent science teaching practices. The Science Council of Canada Study (1984), for instance, includes extensive case studies of senior high school science classrooms in Alberta and other Canadian provinces. From these studies we get a picture of highly teacher-centred science classes, copious note-taking, and laboratory activities designed to help students verify scientific knowledge already imparted by the teacher.

From these studies we get a picture of highly teacher-centred science classes, copious note-taking, and laboratory activitics designed to help students verify scientific knowledge already imparted by the teacher.

These observations largely support Stake and Easley's (1978) case studies of science teaching practices in senior high schools in the United States. They found science teachers seemed to be most concerned about teaching basic facts and definitions outlined in textbooks. Further, even though science teachers claimed that inquiry learning constituted a significant component of science programs at the time, they could find little evidence of scientific inquiry in the science classes they observed.

More recently, Gallagher and Tobin (1987) studied the interactions of teachers and students in Australian high school science classes. They identify four major types of activities which they label as: (1) whole class interactive, (2) whole class passive, (3) individual seat work, (4) small group work. These categories are not unlike the kinds of activities often seen in Alberta science classrooms. Therefore, it may be helpful to examine Gallagher and Tobin's descriptions of these classroom activities in identifying science teachers' perceptions of their role in the classroom.

According to Gallagher and Tobin's estimate, whole class activities characteristically actively engage only approximately 25% of the students. Student involvement predominantly constitutes a small group of students answering teacher questions interspersed in the presentation of content through lecture mode. Moreover, Gallagher and Tobin describe individual seat work activities as tending to be of "low cognitive demand", occurring near the end of the period and often involving students chatting "quietly (but freely) about matters unrelated to science" (p. 542). Small group work activities, on the other hand, consist mainly of students working to collect laboratory data, where students "worked at a pace that allowed the work to consume the allocated time" (p. 543). Moreover, the laboratory work lacked a clear sense of purpose or procedure and was followed by teachers providing students with "ready-made" conclusions.

Few Alberta science teachers can fail to recognize some common features of their own science teaching practice in these descriptions. Quite simply, these activities reflect in large measure the way we ourselves have been taught science, the way we have been taught to teach science, and therefore, not surprisingly, what we have come to view as appropriate for science teaching practice. Importantly, these activities are observable features of the tradition of teacher as expert/lecturer in the senior high science classroom. That is, the appropriateness of these activities stems from the view that the information, knowledge and thinking dealt with in the science classroom flows from the teacher to the students.

Clearly, there is little need for students to be actively engaged in thinking through scientific relationships and explanations if the teacher is not only prepared, but also expected, to do it for them.

If we accept this view, then we must also be prepared to accept two other very important implications. First, the role of teacher as expert/lecturer necessarily puts the learner in a comparatively passive role. Clearly, there is little need for students to be actively engaged in thinking through scientific relationships and explanations if the teacher is not only prepared, but also expected, to do it for them. Second, the teacher as expert/lecturer, by virtue of the changes in the structure and intent of the Science 10 curriculum, is necessarily at a disadvantage when implementing the course.

Consider, for example, the move to link several scientific disciplines within one course of studies. This is accomplished by incorporating concepts common to physical, biological, and Earth science topics both within and between units making up the course. These common concepts require that we stretch our understanding and knowledge of science beyond the specialized discipline boundaries with which we have become so familiar. They ask us to see ourselves as teachers of science, rather than as teachers of chemistry, physics, or biology.

Common concepts ask us to see ourselves as teachers of science, rather than as teachers of chemistry, physics, or biology.

However, our role as experts becomes somewhat tenuous when we are asked to deal with topics (even examples) outside the area of specialization we have so carefully developed throughout our teaching careers. How can we dispense expert knowledge about Earth science topics, for example, if we have spent our time and energy becoming experts in biology, chemistry, or physics? We cannot —

unless we are given sufficient time and are prepared to expend sufficient energy to become experts in all the scientific disciplines. What an overwhelming task! A more practical approach may be to consider a role as teacher that does not demand this type of expertise.

And what of the view of the learner implied in the goal of scientific literacy? Scientific literacy emphasizes the need for all students to function as future citizens in a society very much influenced by both science and technology. It asks us to prepare our students to make informed social choices in addition to preparing them to continue studies in science. Both require our students to be relatively autonomous, independent thinkers. However, it is difficult to see how we can hope to foster intellectual autonomy and independence in our students without encouraging them to take an active role in their own learning.

It is difficult to see how we can hope to foster intellectual autonomy and independence in our students without encouraging them to take an active role in their own learning.

Indeed, current theories of learning recognize the importance of active participation on the part of the learner in the learning process. Increasingly, the learner is seen to construct actively knowledge of the natural world in attempting to account for novel phenomena. Nevertheless, while most science teachers intellectually reject the notion of the learner as a "blank slate" into which we can pour successive bits of information and knowledge, prevalent science teaching practices suggest otherwise. The role of teacher as expert/lecturer primarily reflects a view of learning that depends on a cumulative accretion of knowledge by a largely passive learner.

Critical thinking, problem solving, decision making, cooperative learning, inquiry learning, learning cycle, and integration are some of the key words and phrases that are beginning to surface at meetings of science teachers.

Taken together then, integration and learning theory as applied in the Science 10 curriculum work toward generating a somewhat different view of the role of the science teacher. Essentially they ask us to pay more attention to facilitating the learning of science by our students and less to transmitting the expert knowledge that has resulted from our own learning. An appreciation of the need for active and direct engagement of the learner is central to the role of teacher as facilitator. Significantly, shifting to such a role requires many of us to examine critically both our goals and methodologies for science teaching.

This examination has resulted in a renewed emphasis of several familiar, but often neglected, concepts in the repertoire of knowledge and skills science teachers bring to their classrooms. Critical thinking, problem solving, decision making, cooperative learning, inquiry learning, learning cycle, and integration are some of the key words and phrases that are beginning to surface at meetings of science teachers, such as those I attended earlier this year.

Many of these concepts, as I have already suggested, are not new to teachers or science teachers in Alberta. For example, "Critical Thinking" was the title of an article in Bulletin I issued by the Alberta Department of Education in 1949. It states, "The ideal of democracy is that every person shall understand and exercise" critical thinking in the solution of problems "as an end product of education" (p. 55). Moreover, it relates the pattern of scientific thinking to this type of problem solving. Nevertheless, it is apparent from the case studies of senior high science classrooms that we have come to interpret this repertoire of knowledge and skills about science teaching from a view of science teacher as expert/lecturer. This has resulted in abstracting the elements of these knowledge and skills that enable us to function in this role. In attempting to deal with the new curriculum, we have started to look for new instructional models and teaching strategies. We are tempted to throw out the "chalk and talk" and question our preparation as science teachers.

It is apparent from the case studies of senior high science classrooms that we have come to interpret this repertoire of knowledge and skills about science teaching from a view of science teacher as expert/lecturer.

It is interesting then to examine how science teachers are currently being prepared to assume the rigours of daily classroom life. In the methods course I teach on secondary science teaching we use a text called *Becoming a Secondary School Science Teacher* Trowbridge and Bybee, (1990). This text contains a chapter entitled, "Models for Effective Science Teaching". The chapter spells out specific steps for designing science lessons following several models including the learning cycle model, a cooperative learning model, the 4MAT System, and the Instructional Model (which is based on the constructivist view of learning).

As I work with my preservice science teachers, I have come to recognize that learning these models and the steps in the various models initially has very little impact on their teaching. Many persist in talking about preparing their "lectures" rather than their lessons in spite of my best efforts. It would seem the tradition is pervasive. However, learning instructional models is, I think, somewhat akin to learning the "scientific method". We simply cannot expect to follow the steps and have an appropriate result pop out. As with the scientific method, it is only when these preservice teachers begin to understand the rationale behind the steps that the use of the models begins to breathe some life into their teaching. Thus, it is instructive to examine these models for ideas about science teaching that are common to all.

Each of these "models for effective science teaching" emphasizes direct and active engagement of the learner with the materials and in the learning process. Not just "hands-on", but "minds-on" as well. Moreover, each puts the teacher in a role that is more consistent with that of facilitator than that of expert/lecturer. But changing our roles in the science classroom will not come easily. Change, as we know, is a process, not an event. What can we do then to deal with the new science curriculum effectively? Is it a matter of throwing out the "chalk and talk" and replacing it with new, perhaps different instructional strategies such as those described in the papers that follow?

Perhaps more helpful would be a critical and thorough examination of the strategies and techniques we already use in the classroom.

Learning these strategies, I think, might be helpful. Perhaps more helpful would be a critical and thorough examination of the strategies and techniques we already use in the classroom. Do they make provision for students to become actively engaged in learning? Do they work to keep students on task in a meaningful way or do they allow students to remain passive receptors of the teacher's thinking? Can they be modified to move the teacher away from the role of expert/lecturer and toward the role of facilitator? Let us take our "chalk and talk" strategy as an example.

This strategy sets up a "ping-pong" pattern of teacher - student 1, teacher-student 2, teacher-student 3, etc., interaction where all questions and answers flow from and to the teacher.

A typical teaching strategy that I observe in many science classrooms involves teachers leading discussions or expositions of scientific topics and then jotting notes on the chalkboard or overhead to record important points. Frequently, teachers intersperse this discussion with questions to students. Most often, students respond to the questions with a word or short phrase; the teacher evaluates the response, and then proceeds to the next student and the next question. This strategy sets up a "ping-pong" pattern of teacher-student 1, teacher-student 2, teacher-student 3, etc., interaction where all questions and answers flow from and to the teacher. Typically, the questions are convergent; that is they focus on specific details, generally one word or short answers, requiring little more than recall of information. This pattern of interaction is particularly effective in reviewing previous work in a short time. However, because only one student is involved at a time, and a student often can be let off the "hook" simply by saying "I don't know", it works toward keeping the students in an essentially passive role for a major part of the time.

A modification to this pattern could be to ask other students to comment on the correctness of the first student's response, thereby increasing the participation of students and the level of active engagement with the material. A second modification might be to change the level of demand of the question. For example, instead of asking for one indicator of a chemical reaction (which could be answered by "formation of a precipitate"), we could ask why the formation of a precipitate probably indicates that a chemical change has occurred, or how a student would account for the yellow solid produced when two colourless liquids are mixed.

These are divergent questions; that is, they open up the discussion by asking students to tell us how they are thinking rather than asking them to tell us what they know. At the same time, the teacher could ask other students whether they agree with the first response, whether they have anything to add, or to rephrase the response in their own words. The interaction then flows from teacher to student 1, to student 2, and then to student 3, before coming back to the teacher. At the same time, students are encouraged to listen to (and learn from) one another as well as the teacher.

A second type of interaction involves the teacher asking a question to which the student responds with a word or a short phrase. The teacher then uses this response as an opportunity to elaborate on significant relationships and explanations related to the topic. Transcriptions of science classroom interactions frequently show patterns of consistent teacher elaboration which serve as "mini-lectures" for students. Such teacher-elaboration patterns make it relatively easy for students to remain passive learners. Students soon learn that a word, phrase, or even a relatively simple question is sufficient to get the teacher to elaborate on the relationships between ideas or the explanations they must learn. Learning thus becomes a matter of mastering the teacher's elaboration rather than actively thinking through significant ideas. In such instances, it is helpful to look for ways to make and keep students accountable for generating and testing their own understanding about concepts. This can be accomplished by modifying our questioning or note-generating techniques or by introducing cooperative learning, learning cycle, inquiry learning, or instructional model strategies.

A second type of interaction involves the teacher asking a question to which the student responds with a word or a short phrase.

Learning thus becomes a matter of mastering the teacher's elaboration rather than actively thinking through significant ideas.

Based on the description of these strategies provided in the following pages, it is clear that at least part of our science classroom activities will probably look similar to what occurs in present practice. Students will still be working in small groups, talking to one another as they work. Students will still handle laboratory equipment and use charts, graphs and diagrams to organize the data they collect. Student-teacher interactions will probably continue to include question-and-answer patterns, large group discussions, and even quizzes and unit tests.

This focus on meaningful and personal involvement between and among students is, I think, the key element in learning to work with the new curriculum.

On the other hand, there may well be some notable differences. Visitors to our classrooms will likely notice a greater use of audio-visual tools by students (rather than teachers) in accessing and processing information. Computers, videodiscs, and films are among the tools that teachers will probably provide to help students gather and synthesize the information they need to deal with problems, assignments and projects.

However, the most important difference will be the quality (and perhaps frequency) of students' interactions with one another. These interactions will reflect the kind of collaboration and intellectual independence required to deal with scientific and technological questions in the 21st century. This focus on meaningful and personal involvement between and among students is, I think, the key element in learning to work with the new curriculum. It is not a matter of using a cooperative learning model or the learning cycle, or the 4MAT system to structure all our teaching. Rather, it is a matter of expanding our repertoire of teaching tools so that we can choose among several instructional strategies actively and personally to engage students with the concepts and ideas in their own learning process.

We must develop a strong sense of the rationale behind the role of teacher as facilitator and reinterpret our knowledge and skills about science teaching from that perspective.

Importantly, this does not mean that we never lecture or never use convergent questions. Instead, we must develop a strong sense of the rationale behind the role of teacher as facilitator and reinterpret our knowledge and skills about science teaching from that perspective. As I suggested earlier, learning how depends in large part on understanding why. We have a vast array of knowledge and skills for science teaching at our disposal. The challenge is to put them to use in a different way.

REFERENCES

Alberta Department of Education. 1949. *Bulletin I: Foundations of Education.* Edmonton: King's Printer, 1949.

Gallagher, J.J., and K. Tobin. 1987. "Teacher Management and Student Engagement in High School Science." *Science Education* 71. (4): 535–555.

Science Council of Canada. 1984. *Science Education in Canadian Schools.* Volume 3. *Science Council of Canada Background Study 52.* Ottawa: Canadian Government Publishing Centre.

Stake, R.E., and J.A. Easley, Jr. 1978. *Case Studies in Science Education.* Urbana, IL.: Center for Instructional Research and Curriculum Evaluation, University of Illinois.

Trowbridge, L.W., and R.W. Bybee. 1990. *Becoming a Secondary School Science Teacher.* 5th edition. Columbus, OH: Merrill Publishing Company.

QUESTIONING TECHNIQUES

by Ed Nicholson

INTRODUCTION

Successful teachers have always recognized the fact that teaching is a performing art. Master teachers are masterful and each lesson is orchestrated to provide an optional learning experience. It takes time, and considerable practice, to become an outstanding teacher, and much of that must be devoted not only to learning the material but in developing specific instructional skills.

A key component in the teaching repertoire is the art of effective questioning. A few educators may possess the innate ability to question effectively: most of us have to work at it. Why should we? Because as teachers, "we spend more time asking questions of our students than any other identifiable teacher behaviour." (Kounin, 1970)

A few educators may possess the innate ability to question effectively: most of us have to work at it.

Unfortunately, research by Gall (1970) among others has established that, "about 60 percent of teachers' questions require students to recall facts; about 20 per cent require students to think; and the remaining 20 per cent are procedural."

With a world information base doubling each decade, our students need to learn how to tap into this data base and to do so they must know how to formulate and ask questions.

Hare and Pulliam (1980) suggest that teachers ask literal-type questions because we are still offering a fact-based curriculum. Dantonio, in How Can We Create Thinkers? (1990), suggests that:

> "The reality is that school curricula tend to be text-bound, and textbooks emphasize facts. Therefore, what we teach are facts, and the questions we ask of students rely heavily upon recalling information."

The new junior and senior high science curricula, with their focus on connections and cognitive processes, require teachers to engage students in critical thinking. To succeed in the Information Age our citizens of tomorrow must be able to analyze, clarify, criticize and evaluate. With a world information base doubling each decade, our students need to learn how to tap into this data base and to do so they must know how to formulate and ask questions.

Curiously enough, we spend very little time teaching students how to <u>*ask*</u> questions.

This academic oversight is even more puzzling in a curriculum area where we stress the "discovery approach", "the inquiry method" and the need to "adopt questioning attitudes" (STS Science Education, 1990).

The ability to analyze, hypothesize and synthesize relies on thinking skills which can be best developed by questioning, proposing, discussing and interpreting scientific data

If we are to successfully implement the STS approach to science education, we must engage our students in the higher cognitive processes. The ability to analyze, hypothesize and synthesize relies on thinking skills which can be best developed by questioning, proposing, discussing and interpreting scientific data.

In addition, the new curriculum requires such scientific attitudes as critical-mindedness, suspended judgment, respect for evidence, and willingness to change. These can only be fostered and developed by providing opportunities for students to discuss and debate with their teachers and their fellow students.

QUESTIONING TECHNIQUES AND THE NEW SCIENCE CURRICULUM

Questioning is such an integral part of the teaching-learning process that many teachers do not view it as something which may require improvement or adjustment. When we want to check understanding, we ask a question; if the response is inadequate we question further or simply provide the student with additional knowledge.

In most science classrooms, particularly at the secondary level, a great deal of time is spent by the teacher demonstrating and explaining scientific concepts, helping students to hypothesize and predict, analyzing results and interpreting evidence. The teacher is usually in "expert" mode; i.e., the students regard the teacher as the primary source of scientific information. Even the textbook is subject to interpretation and clarification by the teacher. In this way, the teacher can ensure that students obtain a basic understanding of the scientific knowledge, process skills and attitudes that are essential to mastery of the curriculum.

Now the teacher wishes to stress the impact of science on daily living, to make connections between science and technology, and technology and society.

In the STS approach to science education, the objectives become much broader. Now the teacher wishes to stress the *impact* of science on daily living, to make *connections* between science and technology, and technology and society.

To accomplish these objectives, the teacher must shift his or her role from "*dispenser of knowledge*" to "*facilitator of learning*". Students must be given increased opportunity to interact with the curriculum so that they will understand the way in which science impacts upon daily living.

WHY IMPROVE YOUR TEACHING TECHNIQUES?

Many teachers already provide ample opportunity for their students to discuss and debate the underlying principles of science so that they will become "science literate". Others remain concerned that by de-emphasizing the stress placed in biology, chemistry and physics on scientific knowledge, science will in reality become another social studies course.

Others remain concerned that by de-emphasizing the stress placed in biology, chemistry and physics on scientific knowledge, science will in reality become another social studies course.

The writer believes that in either situation a teacher of science can benefit from adopting instructional techniques that increase student involvement in the learning process. Research indicates that when the ability of both teacher and student to ask and answer questions is enhanced:

- student motivation increases
- students are more critical of the material under discussion
- students' written work shows greater evidence of in-depth thinking and better understanding of essential concepts
- student active participation increases.
  (Blosser,1980; Gall, 1970; Redfield and Rousseau, 1981)

It can also be demonstrated that asking a question in a particular manner increases the possibility that students:

- will engage in non-teacher-oriented discussion
- will request additional information, and
- will be inclined to reflect on their current systems of values and beliefs.
  (Wright and Nuthall, 1970; Eisner, 1985)

SPECIFIC QUESTIONING STRATEGIES

Rowe discovered that the usual teacher wait time was ONE SECOND.

1. Wait Time

1.1 In a 1987 study, Rowe discovered that the usual teacher wait time was ONE SECOND. If wait time was increased to THREE to FIVE SECONDS:

- length of responses increases
- students supply more evidence to support their reasoning
- students do more speculating and higher order thinking
- number of questions asked by students increases
- more students participate in responding
- discipline improves
- students believe teacher places greater value on their response
- student confidence levels increase
- more student–to–student interactions occur.

1.2 Wait time is essential

- between teacher question and student response, and
- between student response and teacher reaction.

1.3 Analyzing wait time may require some outside help. Some possibilities are:

- videotape your lesson
- audiotape your lesson
- have a colleague sit in and measure
- ask the students for feedback.

1.4 Once you have established that your wait time needs to be lengthened, you may wish to try one of these:

- use the wall clock's sweep hand
- do a mental count
- look away from students
- vary the wait time so it is not predictable
- do not preassign the question to a specific student until after the wait time to encourage all students to think

- if necessary admit a poorly phrased question and carefully rephrase without interrupting a response
- if rephrasing a question do not add clues, just clarify the question

2. Levelling

The object of levelling is to provide the most opportunities for correct responses by the greatest number of students.

Levelling is a very simple technique frequently practised by most teachers, but still deserving of mention. The term refers to the strategy whereby the teacher asks questions in direct relation to student ability. Complex, challenging questions are referred to students evidencing high-order thinking skills. The object of levelling is to provide the most opportunities for correct responses by the greatest number of students. This tends to increase risk taking by the class. It also decreases the number of incorrect answers given in any one class period which can result in negative learning

In using this technique it is important to ensure:

2.1 that levelling is not too obvious or condescending.

2.2 that students are consistently challenged by questions asked.

3. Probing

Probing refers to the act of following up on a student's responses.

Probing refers to the act of following up on a student's responses (Dantonio, 1987). It is most commonly used to:

3.1 Request further information (e.g., "Can you explain further?" "I'm not sure I know what you mean." "That's partly correct. Go on.").

3.2 Encourage deeper thinking (e.g., "Why do you think that?" "Can you support that statement?" "Now tie that in with your previous answer." "Then you don't agree with ________'s answer?" "Can you summarize for us then?").

Probing provides an opportunity for the teacher to demonstrate to the students that they are capable of higher-order thinking skills (clarifying, synthesizing, postulating, etc.) and that you expect answers of that calibre. Moving too quickly from one student to another and being satisfied with less than adequate responses may send the wrong signal to the class.

4. Chaining

Sometimes referred to as *redirecting*, chaining is the linking together of questions and responses by a number of students. This may be accomplished in a variety of ways:

Chaining is the linking together of questions and responses by a number of students.

4.1 Ask one student to comment on the answer of another (e.g., "Do you agree? Is ________ correct?").

4.2 Ask several students for their respective answers to the same question.

4.3 Ask one student to elaborate on the answer of another (e.g., "Can you add to _______'s response?" "Can you clarify ___________'s answer or explain further?").

4.4 Pose a set of sequenced questions to a variety of students to develop a particular concept. (This can also be accomplished with one student by probing.)

Gall (1970) maintains that question sequencing correlates positively with reflective thinking and assists students in concept development. Riley (1981) found that redirection was effective at all cognitive levels and resulted in increased student involvement in the topic under discussion.

Perhaps the most important advantage of chaining is the opportunity it may provide for the teacher to move "off-stage" and into the observer role. The writer, in many years of classroom observation, has noted that this particular technique is extremely effective in promoting inter-student discussions.

5. Formulating Questions

It is suggested that teachers provide opportunities for students to ask questions in a low stress, non-threatening environment.

Many of the researchers previously quoted in this outline have commented on the teacher/student question ratio. Studies indicate that less than two per cent of the questions generated in a typical lesson come from students.

As we move from a *product*-oriented to a *process*-oriented curriculum, it becomes extremely important for students to know how to ask questions. As this is another "risk-taking" activity from a student point of view, it is suggested that *teachers* provide opportunities for students to ask questions in a low stress, non-threatening environment. Several suggestions:

5.1 Allow students to prepare questions beforehand to direct to other students or the teacher.

5.2 Experiment with game formats (e.g., Jeopardy or Science Baseball) that require students to generate questions.

5.3 Use role playing activities (e.g., A Community Forum, Environment Panel, Manhattan Project) that provide opportunities for students to question and debate issues in a simulated environment.

5.4 Ask students to develop "real" or "practice" questions for use in the evaluation process.

SUMMARY

The purpose of this outline was to provide the science teacher with both a research-based rationale and some practical ideas for improving their classroom questioning techniques. The research clearly supports a connection between good questions and answers which demonstrate the use of higher cognitive processing. Effective questioning can also be used to increase involvement, spark interest, promote discussion and develop problem-solving ability.

It is important, however, to keep in mind that the techniques described herein are only a means to the end — part of the process in developing superior thinking, creativity and problem-solving ability in future citizen and scientist alike.

Art Costa, in an article entitled "Teaching For Intelligence", concluded:

> "We must convey to students that the goal of their education is intelligent behavior – that the responsibility for thinking is theirs, that it is desirable to have more than one solution, that it is commendable when they take time to plan and reflect on an answer rather than responding rapidly or impulsively, and that it is desirable to change an answer with additional information." (1988)

The new science curriculum will provide increased opportunities for teachers to develop those all-important connections between ourselves and our environment, our society and the world we live in. As Immanuel Kant once said,

> "The mind provides the categories of learning, the world provides the content."

REFERENCES

Alberta Education. 1990. *STS Science Education: Unifying the Goals of Science Education.* Edmonton, Alberta.

Blosser, P.E. 1980. *Handbook of Research: Teacher Questioning Behavior in Science Classrooms.* Columbus, OH: Educational Resources Information Centre.

Costa, Art. 1988. "Teaching for Intelligence." In *Context* 18:22–25.

Dantonio, M. 1987. "Develop Concepts, Question by Question." *Science Teacher* 54(5):46–50.

Dantonio, M. 1990. *How Can We Create Thinkers? Questioning Strategies That Work for Teachers.* Bloomington, IN: National Educational Service.

Eisner, Elliot, ed. 1985. *Learning and Teaching the Ways of Knowing: Eighty-Fourth Yearbook of the National Society for the Study of Education.* Part II. Chicago, IL: University of Chicago Press.

Gall, M.D. 1970. "The Use of Questions in Teaching." *Review of Educational Research* 40:707–21.

Hare, V.C. and C.A. Pulliam. 1980. "Teaching Questioning: A Verification and an Extension." *Journal of Reading Behavior* 12:69–72.

Kounin, Jacob S. 1977. *Discipline and Group Management in Classrooms.* Huntington, NY: R.E. Krieger Publishing Co.

Redfield, D.L. and E.W. Rousseau. 1981. "Meta-analysis of Experimental Research on Teacher Questioning Behavior." *Review of Educational Research* 51(2):237–45.

Riley, Joseph P. 1981. "The Effects of Preservice Teachers' Cognitive Questioning Level and Redirecting on Student Science Achievement." *Journal of Research in Science Teaching* 18(4):303–09.

Rowe, M.B. 1987. "Using Wait Time to Stimulate Inquiry." In Willen, W.W., ed. *Questioning, Questioning Techniques, and Effective Teaching.* Washington, DC: National Educational Association.

Wright, C.J. and G. Nuthall. 1970. "Relationships Between Teacher Behaviors and Pupil Achievement in Three Experimental Elementary Science Lessons." *American Educational Research Journal* 7:477–911.

COOPERATIVE LEARNING

by Olenka Bilash & Dr. Audrey Chastko
University of Calgary

Cooperative learning might be considered a contemporary "buzz word" in educational circles. As such, its nature and the principles upon which it is based are often only superficially understood. The following information is presented in a question-answer format to help you better understand cooperative learning. Examples from the new Grade 10 science curriculum – Unit 1, Energy from the Sun, help to illustrate some of the ideas.

Cooperative learning is a teaching/management technique through which students work together, instead of in competition with one another, to complete assignments.

What is Cooperative Learning?

Cooperative learning is a teaching/management technique through which students work together, instead of in competition with one another, to complete assignments. Assignments contain two components -- an academic component and a social skills component. For example, as an academic assignment, a group of students might be asked to read a selected passage, discuss its implications, and submit a brief report/review about it. At the same time they might also be directed to practise the skill of rephrasing as part of their discussion. The skill of rephrasing would be introduced by the teacher, and students would be given several rephrasing techniques to use in a discussion situation. While students complete the task (or while they are engaged in the process) they are asked to give attention to the social skill. When the process is completed — transformed into a product (in this case, a report) — the teacher assesses the work on its academic merit.

What are the Purposes of Cooperative Learning?

Cooperative learning models have been designed to serve at least four purposes:

- to raise the perceived value of academic achievement among students and to encourage students to help and support peers in their group rather than to compete against classmates.
- to benefit both high- and low-ability students
- to enhance motivation (which occurs when all students believe they have a fair chance at succeeding at the required task)
- to encourage students from different ethnic groups to work interdependently and better understand and appreciate one another.

In addition, teachers of cooperative learning know that it is one teaching/management technique that:

- promotes positive attitudes toward school and the subject area
- develops self–esteem
- assists students in better understanding one another's differences
- develops a sense of community in which students learn that we are dependent on one another.

Cooperative learning functions most successfully as part of a "quarter system".

How Much Time Should be Spent on Cooperative Learning?

Teacher surveys have shown that cooperative learning functions most successfully as part of a "quarter system" in which about one-quarter of class time is spent on each of the following:

- whole class instruction/discussion
- individual activities/assignments
- cooperative learning groups
- reading/viewing/tutorials for content information.

Does Cooperative Learning Mean More Teaching?

Cooperative learning means a somewhat different organization to the learning environment. At first, teachers may have to restructure some of their lessons to accommodate the practice and awareness of social skills.

What Are the Principles of Cooperative Learning?

Cooperative learning is based on five principles developed from research and practice:

- Principle of Distributed Leadership – Group members become more active participants when they are expected to perform and given opportunities to demonstrate leadership skills.

The most effective groups are those in which students come from different racial, social and gender backgrounds and possess varying skill levels and capabilities.

- Principle of Heterogeneous Grouping – The most effective groups are those in which students come from different racial, social and gender backgrounds and possess varying skill levels and capabilities.

- Principle of Positive Interdependence – Students need to learn to recognize and value their dependence on one another.

- Principle of Social Skills Acquisition – The ability to work effectively in a group and, as a group, requires specific socializing skills. These skills — developing social relationships, understanding their nature, using that understanding to get a task done can be taught.

The ability to work effectively in a group and, as a group, requires specific socializing skills.

- Principle of Group Autonomy – Students are more likely to resolve their problems when left to their own resources than when "rescued" by the teacher.

How Does Cooperative Learning Relate to Learning?

Cooperative learning has been brought to the forefront of educational practice because of the opportunities it offers students to learn. It has been found to facilitate four categories of learning:

- Direct application learning – a natural type of learning, intimately tied to the desire to learn to do something; e.g., learning about meteorology, learning to conduct laboratory experiments by doing them.

- Basic skills – the capability of doing something; e.g., reading for direct application (to know how) or for remote use (eventually to be able to learn once having mastered this skill)

- Background knowledge – that which is relevant to learning, though not directly applicable; e.g., mathematics and chemistry contain background knowledge necessary to the study of medicine. Three problems in gaining background information are motivation, retention, and retrieval.

- Personal learning – learning that affects a person's character, tastes, and mental abilities.

What are Some Cooperative Learning Techniques/Activities?

Some of the most frequently used cooperative learning techniques are:

Jigsaw	Teams–Games–Tournament (TGT)
Grouping Games	Student Teams and Achievement (STAD)

(Pages 6 to 11 illustrate these techniques and how they might be applied during the first two weeks of teaching Unit 1, Science 10.)

What is the Teacher's Role in Cooperative Learning?

The teacher must act as a facilitator of learning. A facilitator has distinct responsibilities.

- Train the students (in each of the roles).
- Select the group size (vary according to resources available, needs of the task, skills of the students).
- Assign students to groups (heterogeneous groups have the most potential, as the differences make the group function).
- Arrange the classroom (in clusters).
- Provide the appropriate materials (the same for each member, or different; the same for each group, or different as needed).
- Set the task and goal structure (set goals and expected behaviours).
- Monitor the student-student interaction (eavesdrop, ask questions of the group, make it clear that ALL members of the group are accountable. On a rotating basis, have one student in each group observe the group and give it data on how it worked — use observation form).
- Intervene to solve problems and teach skills (stop the group to teach/identify problems; turn the resolution of the problems back to the group; act as a consultant).
- Assess/evaluate outcomes (how well students completed the task, learned the material, helped each other).

What is the Significance of the Social Skills Component?

Learning and practising cooperative skills — social skills which assist in the completion of a task — in the classroom assist students in the workplace.

Reports now indicate that more employees lose their jobs because of a lack of social skills than because of a lack of technical skills. Learning and practising cooperative skills — social skills which assist in the completion of a task — in the classroom assist students in the workplace.

What Are Some Social Skills That Need to be Taught/Practised?

A successful group is one in which all members contribute equally and to the best of their ability. In order to reach a high level of function, students must learn to:

- praise one another
- encourage one another
- be held accountable for their input
- move between groups quickly and quietly
- use interpersonal and small group skills
- look at one another while discussing
- check for understanding and comprehension

- take turns
- share responsibilities
- paraphrase
- stay with their groups
- use names in interactions
- avoid putdowns of group members.

Functioning as a productive group requires learning how to:

- allot time
- identify purpose
- support each other's ideas
- feel free to ask for help
- ask probing, clarifying questions
- synthesize different ideas
- express one's feelings about the assignment or group process
- criticize ideas, not people
- clarify disagreements
- paraphrase another's ideas
- summarize another's ideas
- ask others to justify their conclusions
- generate several answers or conclusions and select the best for the situation.

How Can I Best Organize My Science Class in a Cooperative Manner?

Many students at senior high school already have developed a high degree of proficiency in social skills. They may also be familiar with the techniques and activities used in cooperative learning from their experiences in other subject areas. However, senior high school science teachers have not traditionally relied on cooperative learning strategies, except possibly for laboratory investigations. Thus it may be helpful to examine the characteristics of cooperative learning as a teaching model.

Senior high school science teachers have not traditionally relied on cooperative learning strategies, except possibly for laboratory investigations.

Cooperative learning provides a structured learning environment based on the following:

- students working together in pairs, triads, fours and up to groups of five, teaching one another and learning from one another

- students TALKING their way through activities, sharing results, sharing responsibilities, accepting responsibility, and developing social skills necessary for future interaction in the workplace and society.

Teachers further enhance the learning that goes on in their classrooms by organizing a talk environment.

How Can I Plan a Learning Environment to Enhance Talk Among Students?

Teachers further enhance the learning that goes on in their classrooms by organizing a talk environment. This involves planning activities to enhance the purposes and contexts of talk about science. Some purposes include:

- to inform
- to move to action (persuade, bargain, plead, justify, argue)
- to inquire (ask, probe, solicit, request, beg)
- to enjoy (fantasize, theorize, dramatize)
- to conjoin (maintain social, cultural relationships).

Contexts of talk include:

- interpersonal communication (inner speech)
- dyadic (two-person) communication
- small group communication
- public communication
- mediated communication.

What Are Some Ways To Develop Talk About Science?

Teachers can plan activities and assignments which offer students the opportunity to experience science in a variety of contexts and to analyze and reflect upon these experiences. The following strategies help to facilitate meaningful talk in science classes.

- Asking students to determine the intent or purpose (e.g., What is the real reason, the specific purpose?).
- Encouraging students to analyze contexts (e.g., How many? Which relationships are present?).
- Encouraging students to select (e.g., Which strategies did I use? Which strategies worked most (or least) effectively? How was this activity structured and why?).
- Providing opportunities for implementing (e.g., Did the language used fit the intended audience, purpose, context, and setting? Did students experience presenting for a variety of audiences, purposes, contexts, and settings?).

How Do I Evaluate or Assess Cooperative Learning?

At the high school level, students are expected to take more responsibility for their own learning. The increased interest in metacognition, metalinguistic awareness, and metathinking reveal the importance of students' awareness of their own abilities to their overall intellectual development.

Through checklists students are invited to offer peer- and self-evaluation of their progress in both social skill development and academic achievement. However, teachers still remain responsible for the assessment and evaluation of academic achievement. A sample evaluation/assessment form is included in Appendix A.

Through checklists students are invited to offer peer- and self-evaluation of their progress in both social skill development and academic achievement.

PLANNING AND IMPLEMENTING COOPERATIVE LEARNING

Three questions to keep in mind when planning a science lesson using cooperative learning:

An Example From Unit 1, Science 10

- Science Content – What's supposed to happen to students' thinking?
- Social Skill – What communication skills must students learn?
- Technique/Activity – What are students and teachers to do?

Suggested Plan for Ten Lessons

Lesson	Science Content	Social Skill	Technique/Activity *See the following pages for detailed examples
1	Issue: Global warming	Eye contact Facing one another	* Jigsaw
2	Global warming	Eye contact Facing one another Praising	Jigsaw
3	Weather maps	Praising/encouraging Checking Recording	* Group Roles
4	Weather maps	Praising/encouraging Checking Recording	Group Roles
5	Weather maps	Praising/encouraging Checking Recording	Group Roles
6	Review weather symbols and systems	Using first names	* Grouping Game
7	Properties of water Hydrologic cycle	Taking turns	* STAD Teacher Lecture
8	Properties of water Heat capacity	All skills to date	* STAD Experiment
9	Properties of water Expansion/freezing	Paraphrasing	* STAD Film or Experiment
10	Review	All skills	*TGT
11	Quiz (STAD)		

In the "jigsaw" method of cooperative learning, participants work in small groups and they rely on one another. Each member researches a part of the major topic or issue and that part is essential information to the whole group. Cooperation and trust become necessary for success. The activities outlined below follow such a "jigsaw" strategy.

They have both academic and social objectives. The academic objectives are to develop:

- students' interest in the unit about energy from the Sun
- students' understanding of the greenhouse effect, the ozone layer, weather forecasting and global warming.

The social skills objectives are to develop students' awareness of the importance of, and skill in using:

- eye contact and facing a person when communicating
- praise when communicating.

Students work on the activity in the same groups of three over two consecutive lessons (Lessons 1–2) for approximately 30–40 minutes.

Materials Required:

Matthews, Samuel W. (1990). "Under the Sun – Is Our World Warming?" *National Geographic*, 178, 4: 66-99.

Suggested Lesson Sequence:

1. Use a "T-bar" format shown below to stimulate students' ideas about "praising":

Praising

What Does it Look Like?		What Does it Sound Like?
patting someone on the back smiling leaning forward		good job! nice work! way to go!

2. Distribute the article to students and briefly introduce the topic.

3. Divide class into groups of three.

4. Ask students in each group to choose a number (1, 2, or 3).

5. While students engage in the following sequence of activities, the teacher:
   - circulates and listens in to discussions
   - reminds students about "eye contact/facing one another", if necessary
   - raises questions to assist students in clarifying information
   - assesses students' levels of understanding and leadership skills to determine which students might make the best groups for the STAD activities in the following week

LESSON 1

Group	1	2	3
Skim	Read p. 66–71 for overview.	Read p. 66–71 for overview.	Read p. 66–71 for overview.
Read Silently	p. 74 – Earth's Thermostat: The Greenhouse Effect. p. 78 – Fever Chart of a Warming Planet	p. 82–83 – Forecast from a Clouded Crystal Ball	
Discuss	Discuss main ideas with another #1. Practise eye contact/facing one another.	Discuss main ideas with another #2. Practise eye contact/facing one another.	Discuss main ideas with another #3. Practise eye contact/facing one another.
Create Visual	With partner, create a visual to explain the main ideas.	With partner, create a visual to explain the main ideas.	With partner, create a visual to explain the main ideas.
LESSON 2			
Practice	Find another #1. Practise explaining the content. Listen to partner explain content. Share each other's visuals. Revise visuals, if necessary. Practise eye contact/ facing one another. Practise praising.	Find another #2. Practise explaining the content. Listen to partner explain content. Share each other's visuals. Revise visuals, if necessary. Practise eye contact/ facing one another. Practise praising.	Find another #3. Practise explaining the content. Listen to partner explain content. Share each other's visuals. Revise visuals, if necessary. Practise eye contact/ facing one another. Practise praising.
Teach	Return to original group. Present information, with assistance of visuals, to #2 and #3. Practise praising.	Return to original group. Present information, with assistance of visuals, to #1 and #3. Practise praising.	Return to original group. Present information, with assistance of visuals, to #1 and #2. Practise praising.
Assessment	Complete self and group assessment forms.	Complete self and group assessment forms. See Appendix A.	Complete self and group assessment forms.

Academic objectives for this activity are to:

- help students become familiar with factors that influence the explanation and prediction of weather patterns
- develop student understanding of the complexity of the interactions between these factors and the difficulties associated with making accurate weather predictions.

Social skills objectives are to develop students' awareness of the importance of, and skill in:

- using encouragement when communicating
- checking for understanding when communicating
- acting as group recorder of ideas when communicating
- practising "eye contact/facing one another" and praising.

Students work on the activity in the same groups over three consecutive lessons (Lessons 3–5) for approximately 20–30 minutes

Materials Required:

- Data to provide weather conditions over a period of several consecutive days, after which some significant weather phenomenon occurs. (For example, provide students with Accu-Weather maps for four or five days prior to the tornado which occurred in Edmonton, the weather map the day of the tornado, and weather maps for several days after the tornado.)
- Questions to focus the group work.

Suggested Lesson Sequence:

LESSONS 3–5

1. Use a T-bar to encourage students to share ideas about "encouraging". (See Lesson 1.)
2. Repeat for "checking" and "recording".
3. In each group, students will select to be #1, #2, or #3. Over the three lessons, each student will practise each role:

Lesson	1	2	3
3	praiser/encourager	checker	recorder
4	checker	recorder	praiser/encourager
5	recorder	praiser/encourager	checker

LESSON 3

Provide all groups with weather maps for the first three days of the weather sequence. Use the maps to focus students' attention on the symbols necessary for reading a weather map and the relationships between weather conditions and meteorological data.

Sample Questions:

1. What symbol(s) indicate: (a) a warm front? (b) low atmospheric pressure? (c) precipitation?

2. What meteorological conditions seem to be associated with precipitation? stable weather?

3. What inferences can you make about the air found in an area of low pressure? an area of high pressure?

LESSON 4

Provide all groups with weather maps for the remaining three days of the weather sequence. Ensure students recognize the sequence of weather maps (e.g., Day 1, Day 2, Day 3, etc.) but do not indicate that the weather will change significantly on the next day. Use the sequence to focus students' attention on trends and patterns in weather systems.

Sample Questions:

1. What are the major weather conditions across Canada on Day 1 of your weather sequence?

2. What happens to these weather systems between Day 1 and Day 5? Do they stay in the same place or do they move?

3. Can you identify any trends in weather patterns across Canada, based on your examination of these five weather maps?

4. What might you predict the weather should be like in Alberta on Day 6 of this weather sequence? In Ontario?

LESSON 5

Provide students with the remaining weather maps for the weather sequence. Have them focus first on the weather condition which occurred on Day 6 (e.g., the tornado in Edmonton) and compare their predictions (from the previous lesson) with the actual weather conditions. Provide students with dates and details of the weather sequence, then have them track the weather system over the remaining maps.

Sample Questions

1. How does your prediction for Day 6 compare with what actually occurred?

2. What was the effect of the weather on Day 6 on the population in the area? Would an accurate weather forecast have helped to lessen the impact of this weather system on the people who lived in the area?

3. What are some of the problems you (and meteorologists generally) encounter in making accurate predictions about weather?

Activities for Illustrating Group Games

Academic objectives for this activity are to review content covered in previous lessons.

The social skills objective is to develop students' awareness of the importance of, and skill in using one another's names when communicating.

Materials Required:

A set of cards (See Appendix B)

LESSON 6

Suggested Lesson Sequence:

1. Use a T-bar to have students share ideas about the importance of "using names" when communicating. (See Lesson 1).

2. Distribute one card to each student.

3. Have students circulate among each other, looking for a word, definition, and weather symbol that match. The triad formed will stay together for the next activity.

(More information about grouping games is provided in Appendix C.)

Activities for Illustrating STAD - Student Teams and Achievement

The academic objective of this activity is to develop student understanding about the properties of water (i.e., the hydrologic cycle, heat capacity, expansion on freezing).

The social skill objectives are to develop students' awareness of the importance of, and skill in taking turns and paraphrasing when communicating.

Suggested Lesson Sequence:

LESSON 7

1. Use a T-bar to develop students' ideas about the contribution that taking turns makes to ensuring that all members of the group feel valued and accepted.

2. Teacher presents and discusses new content regarding the properties of water.

3. Students form teams of three members (heterogeneous groups assigned by the teacher based on feedback gathered during activities in previous lessons.)

4. Teacher provides students with work sheets or questions dealing with the content covered in the first part of the lesson, and announces a quiz on the content for the end of the week.

5. Students complete work sheet or question assignment. They also develop questions to quiz one another to verify their comprehension of the content and to relate it to other content they have previously studied.

LESSON 8

1. Briefly review all of the social skills introduced and practised to this point. Invite students to comment about how using these skills assists them in their group work. Remind students to practise all these skills.

2. Teacher presents new material to class, possibly through laboratory investigation.

3. Students move into the groups assigned in Lesson 7. They complete a work sheet or a set of questions related to the laboratory investigation.

4. Each team makes up questions regarding the laboratory investigation. The students also quiz one another about the questions on the work sheet.

LESSON 9

1. Use a T-bar to develop students' ideas about paraphrasing.

2. Teacher presents additional information about the properties of water, either through a laboratory investigation or film.

3. Students work in their previously assigned triads at a worksheet provided by the teacher. They continue to develop questions to quiz one another about the content of the film.

Activities for Illustrating TGT -- Teams - Games - Tournaments

LESSON 10

Suggested Lesson Sequence:

1. Remind students to practise all social skills while working in class.

2. Students work in their previously assigned triads. They compose ten questions regarding the content of the unit and record them on small index cards.

3. The teacher also composes questions regarding the content of the unit and records them on small index cards. All questions are shuffled together.

4. Each triad assigns a value (2, 4, or 6 points) for the correct answer to be given by each member during the tournament. Usually students decide to let the strongest team member try for six points.

5. Shuffled cards are dealt among teams. Each team finds a challenger and all teams go to match. Within each match, the members vying for six points draw against each other; the members vying for four points draw against each other, etc. Each pair takes one turn. Both teams should record the scores for the match. The teacher circulates to confirm correct answers and rule on ties or disputes.

6. Each team records its total points. This score could represent a part of the term work grade for each team member. If recorded, it could be used for comparative purposes after the next TGT. As an incentive, teachers might offer bonus points to teams that improve over a certain percentage of their previous test score.

Self Assessment Form

How well did I cooperate/learn?

Self Assessment – Social Skills

Rank yourself on a scale of 1 (low) to 5 (high) on the following:

I maintained eye contact with group members when I spoke	1	2	3	4	5
I faced into my group when I spoke	1	2	3	4	5
I looked at others when they spoke	1	2	3	4	5
I felt comfortable praising	1	2	3	4	5
I enjoyed being praised	1	2	3	4	5

I am strongest in ____

____

I need to improve in ____

____

My goal for next class is ____

____

Group Assessment

Rank your group's performance on a scale of 1 (low) to 5 (high) on the following:

We practised eye contact/facing one another.	1	2	3	4	5
We practised praising.	1	2	3	4	5
We tried.	1	2	3	4	5
We presented information well.	1	2	3	4	5
We stayed on task.	1	2	3	4	5
I felt comfortable in this group.	1	2	3	4	5

As a group we were strongest when ____

____

We need to improve in ____

____

Our goal for next class is ____

____

Self Assessment – Content

Rank yourself on a scale of 1 (low) to 5 (high) on the following:

I can describe the greenhouse effect.	1	2	3	4	5
I know what the ozone layer is.	1	2	3	4	5
I understand the way meteorologists forecast through clouds.	1	2	3	4	5
I can explain why the planet is warming.	1	2	3	4	5

I learned the following well ____

____

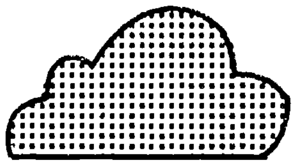
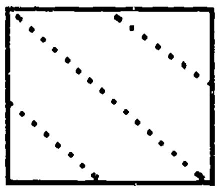
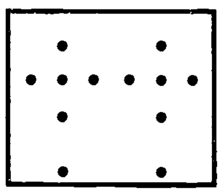
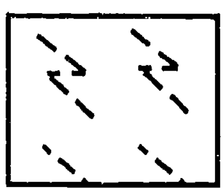
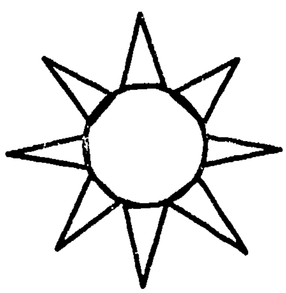
I need more time to understand the following ______________________________

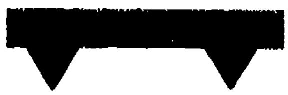
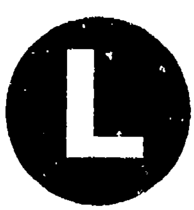
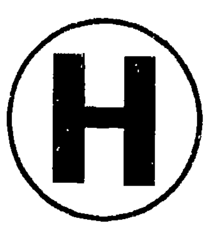
____

I want to know about ____

____

Grouping Cards for Lesson 6

	CLOUDY	Occurs when a mass of air is cooled below its dew point.
	RAIN	Precipitation that forms as droplets of water condense and become large and heavy enough to fall from a cloud.
	SNOW	Precipitation that forms as water vapour condenses when the temperature of the air is below freezing.
	THUNDERSTORMS	Formed when warm moist air is pushed rapidly upward, accompanied by equally rapid downdrafts of cool air.
	SUNNY	Bright and cheerful light; associated with pleasant weather.

	COLD FRONT	Occurs when cold air pushes warmer air ahead of it.
	WARM FRONT	Occurs when warm air pushes colder air ahead of it.
	STATIONARY FRONT	Boundary line between a cold air mass and a warm air mass.
	LOW PRESSURE	Produced by a warm air mass; travels in a circular counterclockwise direction in northern hemisphere.
	HIGH PRESSURE	Produced by a cold air mass; travels in a circular clockwise direction in northern hemisphere.

More Information About Grouping Games

Grouping games offer students an opportunity to mingle. Each game consists of a perfect number of card sets needed by the group. If there are 12 students you may have six sets of two, or three sets of four, or four sets of three. If there are 17 students you may have five sets of three and one pair, three sets of four and two trios, or three sets of five and one pair. Every class member should obtain one card, on which a word, phrase, question, or definition is written. Each card must be read and matched (through a definition, answer, sentence completion or association).

Grouping games are an excellent means of:

- movement (change of pace)
- reviewing comprehension
- testing knowledge of key concepts
- extending ideas into the real world
- applying knowledge to other areas
- practising skills
- motivating students
- promoting creativity
- getting students to talk to one another
- using time wisely to group students for an activity

There are many types of grouping:

- definitions with proper word
- antonyms
- one half of a sentence with the other half of a sentence, which then is true and makes sense
- problems with appropriate advice
- synonyms
- questions with appropriate answers

Definitions

Students are asked to draw a card and then circulate among other students asking them to read/re-state the word or phrase (definition) on their card. If the phrase on one card describes the word on the other, students link together to form a pair.

This can also be done with trios by adding a "picture" to a third card. Then the students must look for a word, phrase and picture that match.

Once students have formed a pair or trio they may be asked to play a game, write a joint story, make up some definitions . . . the possibilities are endless.

Other Ways of Grouping

Students are asked to draw a card and then circulate among other students asking if their card is:

- a matching problem or matching advice
- the other half of a sentence which, when combined with theirs, is true and makes sense
- a matching question or answer
- an opposite to their word
- a synonym to their word

When the phrase or word on one card matches that which is on the other, students link together to form a pair.

Students may also be grouped to complete certain tasks. Groups can be created

- in alphabetical order
- by proximity (seating)
- by numbering off
- by ability level (assigned by T)

LANGUAGE FOR THINKING AND COMMUNICATION

by Tara Boyd

Teachers know that students do not simply absorb new concepts by listening to someone explain them, that students must internalize science concepts and skills through their own communication processes (reading, writing, speaking, listening and viewing). This section presents some activity ideas, using these five communication processes, which can form part of three important recommended components in the senior high science program.

- The Science Learning Log
- The Portfolio
- The Research Project

Students must internalize science concepts and skills through their own communication processes (reading, writing, speaking, listening and viewing).

The communication activities you choose for these three components can help students make science concepts and skills their "own", relating them to their own lives, exploring a wide variety of applications and connections to other knowledge and experience, and consolidating the learning in a way they will remember.

Using these communication activities can also save you time, by helping you and your students quickly pinpoint their learning difficulties, and find strategies to overcome them. You will also contribute enormously to students' development of better reading, writing and discussing/presenting skills, which in turn yields dividends when you need to assess such skills in science classes. Imagine getting in stacks of lab reports that you can actually enjoy reading, or conducting a lesson based on a text chapter that everyone has actually understood on their own!

THE SCIENCE LEARNING LOG

When students write down notes in science class, they often do not fully understand what they've written. They are sometimes learning a concept for the first time, or copying lists of information to be reviewed later and memorized. The language of their formal notes is usually not their own, but the teacher's definitions or foreign terms.

A "Learning Log" is a more powerful tool than traditional science notes. It serves to increase students' depth of understanding, using spontaneous writing as well as note-taking. Very simply, students divide their books into two sections (an easy way is to divide each page of their books into two columns). One section or column is for their standard formal notes, tracking the information content of the science lesson. The other is for spontaneous writing based on those formal notes. In that column, questions, predictions, summaries, observations, fleeting associations with personal experience and other knowledge, applications or frustrations can be recorded. Such writing can provide a rough data record for laboratory work, a way to explore a topic further or review the concepts being learned. Often such writing will lead to an initial proposal or plan for a research project.

Spontaneous writing can meet our students' need to process new learning.

During a class lecture you might want to stop now and then to allow students a few minutes to reflect on the new learning and write spontaneously in the right column. As students write, you can walk around and, by reading over their shoulders, gain a quick and accurate idea of their level of understanding.

Such writing is not for an audience, so logic and polish and surface considerations like spelling are not important.

Several suggestions follow for getting your students to write spontaneously in ways that will directly increase the depth and longevity of their science learning.

1. How Does Writing Help Students Learn?

Spontaneous writing can meet our students' need to process new learning; to "chew" it through and make meaning of it for themselves. To do this, they need time and space to link the new concepts you are presenting to their past experiences and to things they already understand. As students begin to think their way through a new concept, they are often swimming in a whirlpool of mental associations, bits of information, half-formed questions, even feelings that twinge as they try to make sense of the new learning and place it somewhere in their current picture of reality. When you pause in your teaching and give students time to reflect and write about all the things running through their heads, you allow them to internalize the new learning and connect it to what they already know.

This kind of reflection happens in quick periods of writing produced not for grading but for students' personal use, sorting through their thoughts on paper. Such writing is not for an audience, so logic and polish and surface considerations like spelling are not important. The emphasis is writing as a *means* to an end – the end being the formation of a new idea in the head. The written product is *not* an end in itself, to be handed in and graded. Obviously, there is an important place in science instruction for writing polished into clear, concise prose intended for grading, and this will be dealt with later.

Any writing that you have students do in science class helps them learn more effectively, for five reasons:

a *Writing is permanent.* It captures fleeting thoughts and helps students to hold on to an idea long enough to work it out before it vanishes.

b. *Writing is explicit.* A student is forced to clarify and focus what is sometimes a tangle of thought as soon as she/he tries to put it into words. When we feel mentally blocked in our problem solving, writing is a way to discover ideas stored away that we'd forgotten about, and watch connections unfold in front of us.

Writing forces them to draw on relevant knowledge, review and consolidate the meaning, extend the meaning into other applications and then. later, reformulate and review the concept in light of new concepts presented.

c. *Writing is active.* Students usually remember most of the meanings they have actively constructed and written for themselves in their own words. To do this, students must do some hard thinking. Writing forces them to draw on relevant knowledge, review and consolidate the meaning, extend the meaning into other applications and then, later, reformulate and review the concept in light of new concepts presented. It is not enough for the teacher to review and consolidate the learning for the students. They've got to do it for themselves.

d. *Writing requires organization.* To write, students must relate the parts of the idea in some meaningful way. Thought is multidimensional; writing is more linear. Words string into sentences, winding a trail that lends logical order to the spinning wheels of thought.

Thought is multidimensional; writing is more linear.

e. *Writing connects to the self.* People remember most of the things that are tied in their experience to some kind of emotional memory, or image or story. These aspects of experience are more real to students than abstractions; storytelling, imagination and feelings are the "human" ways of knowing that students have relied on intuitively since birth. When students write spontaneously about memories, associations and feelings connected with abstract science concepts and issues, or invent stories applying science concepts or skills, or write dialogues arguing two sides of a science/technology/society issue, the learning becomes memorable.

2. What Is Spontaneous Writing, and How Is it Used in Class?

Past writing "failures" may have taught them to distrust their own writing, and they become paralyzed.

Spontaneous writing is simply non-stop writing for a short period, say five to ten minutes. What flows out onto the page is a kind of mental dump. The writer suspends critical judgment of the writing produced – spontaneous writing is not the time to worry about sentence structure or word choice or tone. The product is not what's important (it's often just "verbal soup" anyway). The thinking process that occurs (constructing, connecting, clarifying, consolidating meaning) when you have students write out their ideas at crucial learning times is the goal here.

Students can write spontaneously in response to a teacher's specific question, or to reflect on what they've just learned, or to recall the process they used to solve a problem, or to generate questions, explore personal associations, brainstorm applications, sort out their opinion on an issue, or any number of other writing-to-learn purposes in science.

Some students will have trouble when they first use such writing in science class. Somewhere in their growth as writers they may have learned to fear and resist writing as an agonized labour squeezing out an orderly succession of words that must be grammatically correct, spelled right and punctuated properly. Past writing "failures" may have taught them to distrust their own writing, and they become paralyzed. Others like to compartmentalize their learning. They may be quite accustomed to writing in other courses, but are confused when science teachers employ the same learning activity.

These students, like many adults who fear and resist new things, have to be nudged along until they discover the value of what they're doing. Share models of student spontaneous writing, perhaps on the overhead projector. Show them unique insights, questions and connections uncovered through their spontaneous writing. Be explicit and discuss with them how these writing exercises can actually help them learn and remember science concepts and skills. And be patient. Remain positive and applaud their first attempts.

3. Specific "Spontaneous Writing" Activities to Use in Learning Logs

a. Lesson Response (teacher as audience)

After a lesson about a particular concept/skill, ask students to write, simply and spontaneously, a brief response to you, almost like a "letter", about what they are learning. If you like, you can provide prompts such as the following for students who don't know what to write about (some teachers just write these on a chart and post it somewhere in the room for students to glance at when writing a lesson response):

- What part are you finding easiest to learn?
- What parts did you already know, or had figured out in your own life?
- What part is still confusing for you?
- What one thing did you find out that you didn't know before, that is really interesting?
- How do you feel right now about what we're doing?
- What part do you find is somehow meaningful in your life? How does it relate?
- Does any part relate to what you're learning now in another subject area? What's the connection?
- What questions have occurred to you (general or specific, related to the material or not) that we haven't addressed?

Lesson responses also work really well when the class is discussing a science-technology-society issue. Stop everything (especially at points where the discussion is particularly heated and certain students who need longer thinking time before offering their opinion are not participating) and have students write spontaneously what they are thinking, what points they agree/disagree with, what examples in the world they can think of. Or have them suddenly write about the issue from a totally different perspective (e.g., in the midst of a discussion on deforestation of Vancouver Island, ask students to assume the role of a representative from MacMillan-Bloedel Pulp and Paper Company who has been listening to the class remarks so far, and have them write spontaneously that person's thoughts and feelings about the issue).

Lesson responses also work really well when the class is discussing a science-technology-society issue.

The important thing is to encourage open-ended writing. You **do not** want this to degenerate into a list of questions that students must answer. What you're after are their honest responses to what's going on with them in their science learning. It's as much a chance for them to discover their own links with past experience/knowledge as it is for you to get an immediate sense of how well the students are processing the information you're presenting, and why some are having difficulty.

The big advantage of peer responses to spontaneous writing is the saving of your time.

b. Lesson Responses (peers as audience)

Students write personal response summaries to a lecture or text reading, and exchange this "letter" with a peer partner, who writes a response back to them. In such an exercise, many honest questions will emerge that students may be too intimidated to ask you, and students often discover shared associations, difficulties and thought processes with their peers. The big advantage of peer responses to spontaneous writing is the saving of your time.

c. Summarizing a Concept

As you walk around the room while students write, you will know at a glance who understands the concept and who doesn't.

After "teaching" a concept (whether through lecture, demo, text reading or other method), stop the class and have students write about it. Say something like "Okay everybody, without saying a word to your neighbour, without asking a single question, without stopping to think, start writing an explanation of concept X as you understand it. Use your own words. Make it so clear that someone in this class could read it and understand it. Don't worry about spelling or sentence structure or repetition. Worry only about writing as clear an explanation as you can."

As you walk around the room while students write, you will know at a glance who understands the concept and who doesn't. More important, they, too, will quickly come to realize just how comfortable they are with the new learning.

Variations: You might have students exchange their "explanation" with a partner, read each other's, then respond orally or in writing (Did it work? Was it clear? Was it accurate?). Try having selected students share their written summaries. Give lots of positive encouragement and honest praise or you'll squelch future spontaneous writing attempts. Try having the students pretend they are writing an explanation for a younger sibling, or a junior high student or some other audience. Try asking them to develop in writing an example showing the concept in action (they would describe the concept through the example).

d. End-of-Class Summaries

Some teachers have students spontaneously write a brief summary in the last five minutes of each class. Such an exercise helps students recall and consolidate the learning of the day. You might try giving students focus questions at first to get them started, such as:

- What do you know now that you didn't know when you walked in today?
- How can this new knowledge/skill help you in your own life?
- What further question(s) do you still have at this point?

e. Problem Solving in Writing

Students describe the process they went through in solving a specific problem immediately after they finish (even if they got stuck and can't solve the problem). The point here is to help them become aware of how they found their way through the problem, then compare this to how others solved the problem, and re-assess the efficiency of their own problem-solving process (how could they improve their approach to a similar problem next time?). Have them share their solution process with a partner, or with a small group. Or lead the class through a suggested method of solving the problem. Then have the students go back to their writing-about-their-solution process, evaluate it and write again – this time about alternative approaches to the same problem, or elements they hadn't considered or what they might do differently next time.

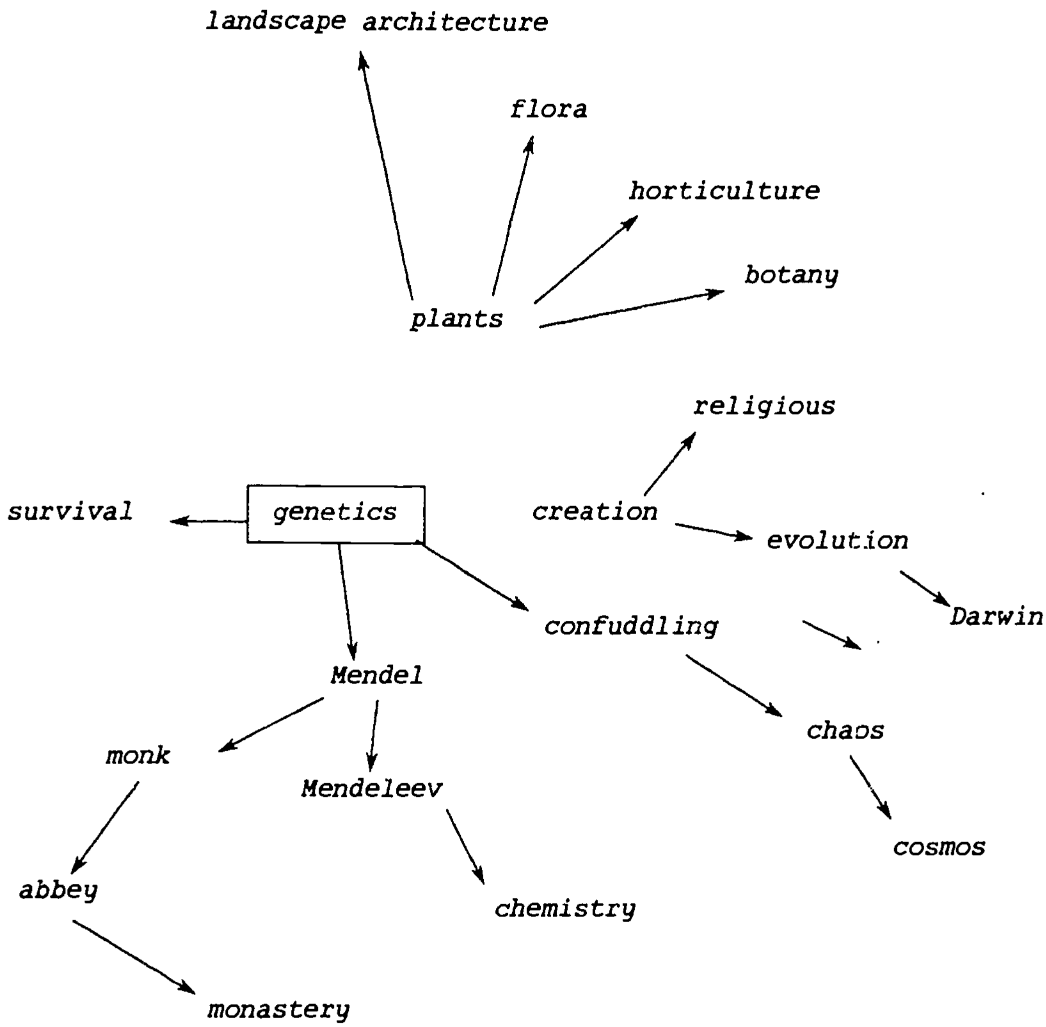
f. Clustering (also called mind mapping, networking and webbing)

When starting a unit, give students a key word or concept to "cluster" (jot down any ideas or experiences they associate with that word). They write this word or phrase in the centre of their page with a circle around it, then quickly jot down key words or phrases to represent things they associate with that root word. These associations form "branches", with one association leading to another until the train of thought is exhausted. Then the writer begins again at the root word, starting a new branch of idea

Clustering continues until an idea forms clearly enough for the student to want to start writing about it.

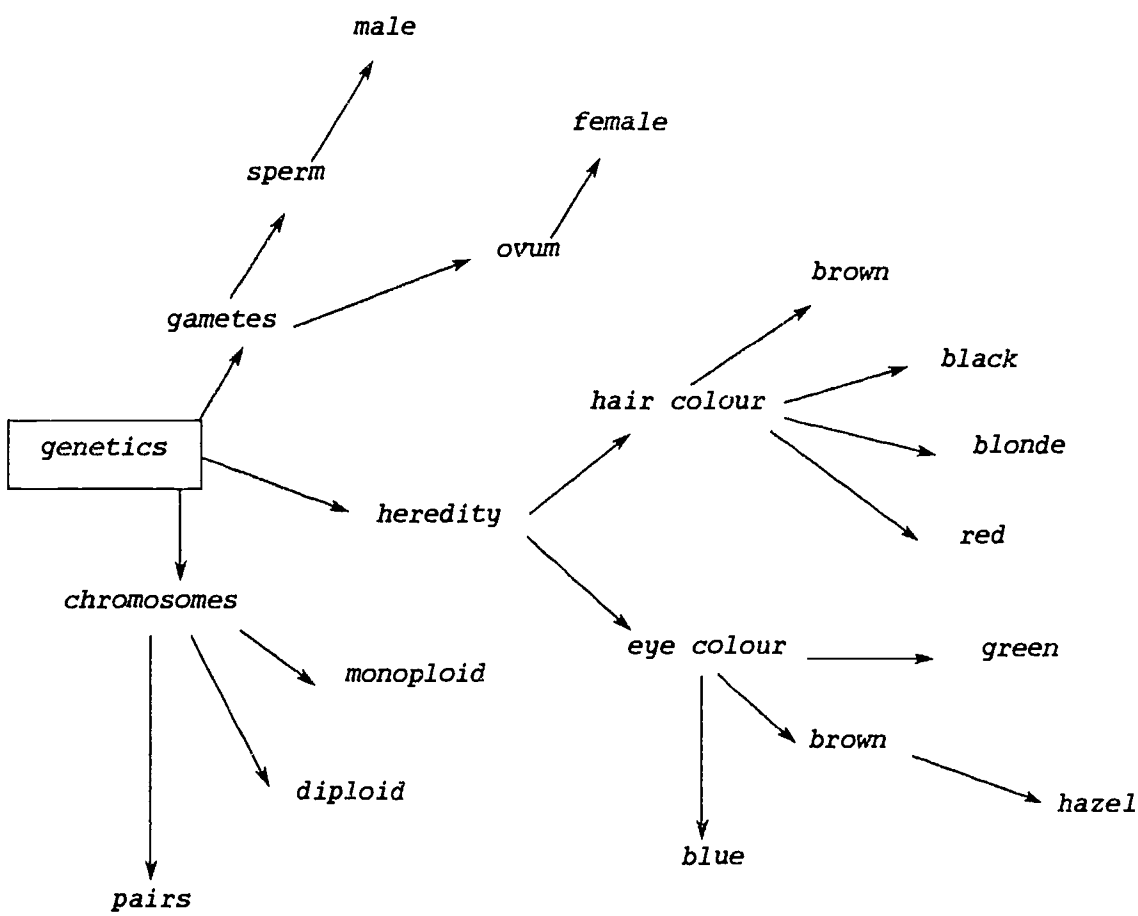
clusters. The clustering continues until an idea forms clearly enough for the student to want to start writing about it. At that point there is a shift – the student quits making "idea branches" and actually starts to write about an idea that has twinged tl motivation to write. This shift is important, for it is the main purpose of the exercise.

Sample 1 – Biology 20 Student



The theory was that the universe was created from a "big bang". From there, Earth was created. You could think of it as one very large evolving cell, producing and bringing forth new and independent things. Then came the formation of man and animals, each evolving from single cells with their own characteristics and mechanisms for survival.

Sample 2 – Biology 20 Student



Gametes are any sex cell (obviously male or female, as those are the two most common sexes). They are produced through or by a process called mitosis (asexual reproduction). Gametes may also be cells of both sexes (again, most likely male and female) so that when mitosis (cell division) occurs, you get another cell of either male or female gender — you would not likely get a homosexual cell.

* Note the diagnostic value to the teacher of the students' writing their conceptions of the term explained in their own words. The teacher can pick up on any misunderstanding and deal with it.

This exercise helps students consolidate their background knowledge about a new area of learning, and shows you what their mental associations with the area are. Clustering-into-writing is also an excellent way to help your students focus and begin to explore the material you want to present.

4. Evaluating Spontaneous Writing

You often have to do something at first to make students accountable or some just won't do it (at least, until they find out how much fun it is).

With all personal response-type writing, you often have to do something at first to make students accountable or some just won't do it (at least, until they find out how much fun it is). Try allowing in-class time for spontaneous writing. Give students set time limits – three to seven minutes is usually lots – and insist that there be **no** talking during that time. In true spontaneous writing, you insist that they write without stopping, without even taking their pencils off the page. Prompt them by asking them to put into words, as specifically as they can, what they are thinking, wondering, realizing about the lesson.

Don't try to grade it or even read it all – you don't have time. Some alternatives are: have peers read their partners' work as much as possible; have selected students share their work with the class; find some interesting ones yourself and display them on the overhead (often this prompts the "cooler" students to get involved so they, too, can get into the spotlight). (If you have a class that absolutely must know that "this counts for something", have them keep all this spontaneous writing in a separate section or notebook and turn it all in periodically. At this time you can flip through it, comment on the interesting bits and assign a holistic mark. Refer to the sample marking key at the end of this section.)

In the case of lesson responses that actually are letters to you, which contain students' questions/areas of confusion and other valuable information, try having a few students go through these and make a list of all the questions for the class. Then both you and they can proceed to find the answers and fill in these "gaps" in knowledge.

5. More Ideas for Learning Logs

What follows is a list of specific examples of spontaneous writing activities that can be incorporated into learning logs to supplement students' information notes:

- Brainstorm alone, on paper or in groups, all the questions they have about a new concept.
- Quantity, not quality, is the key in brainstorming. Judgment of ideas must be suspended while students try to shake out ideas. In brainstorming, try having competitions for "the most ideas", and celebrate the most unique offerings.

- Spontaneously write predictions of experiment outcomes, chemical reactions or behaviour of objects, based on previous knowledge.
- Brainstorm possible applications for a new concept in their daily lives and the world around them. Or brainstorm possible new applications for a concept.

Brainstorm examples in students' personal experience of their new science learning.

- Brainstorm examples in their personal experience of their new science learning.
  Examples:

  - *How many things can you think of in your personal experience where chemical changes occur in aqueous solutions? (Then have students choose one of these and explain in writing exactly what they think the chemical change is.)*
  - *In groups, list three solutions you encounter in daily life. Figure out together what the properties of these solutions are, relating what you know already about properties of electrolytes, non-electrolytes, acids and bases. Then find an interesting way to present your findings to the class.*

- Compare something new to something you are familiar with, and explain the comparison (this is called "writing similes"). For example:
  Science 10, Unit 2, No. 3: *A cell is like a__________ because ___.*
  (A cell is like a factory: it takes in raw materials, produces new materials and gets rid of wastes.)

- Imagine three ways this new thing might be used, but isn't.
- If this new thing were an animal, what animal would it be? (and why?)
- What person would it be?
- Picture the new thing in your mind as if you are seeing it for the first time. What do you notice first?
- Imagine you are observing the outcome of a lab experiment you are about to perform. Describe in detail what you see.
- For an abstract concept, process or set of relationships, imagine what colour it is, what shape, what place it is, what ecological system it could be thought to be part of (what depends on it? what does it depend on? what does it eat? what eats it?).
- Imagine you have been studying this thing for a long time. Write a journal entry explaining the latest thing you have learned about it – or explain how you see this thing after a lifetime spent studying it.

- Have students assess the learning they demonstrate in their own tests, then write specific learning goals for themselves. Help them design learning strategies to achieve their goals.
- After group work, have students evaluate their individual and group progress toward mastery of one or two particular group skills that you have asked them to concentrate on. The following list of group skills may be found in *Together We Learn* (Clarke, Wideman and Eadie, 1989). Asking questions, asking for clarification, checking for others' understanding, elaborating on each others' ideas, following directions, getting the group back to work, keeping track of time, listening actively, sharing information and ideas, staying on task, summarizing for understanding/paraphrasing.

THE PORTFOLIO

The portfolio in science should contain a large variety of written assignments for grading. You might include the learning log, or simply have students write in any combination of the activities suggested above for their portfolio. Further suggestions follow.

1. RAFTS Writing Assignments

Role - Audience - Format - Topic - Strong Verb. The RAFTS formula creates imaginative writing exercises to help students adopt new perspectives on a science issue, or discover divergent applications for a concept, or make sudden connections between themselves and their learning.

To start, decide the specific topic that will be the focus of the writing.

For example: photosynthesis, energy conversion, weather patterns, conservation of energy, food chains (webs).

Then make a list of possible "roles" the students could assume in discussing the particular science topic you are working on, and another list of potential "audiences" that their remarks might be directed to. These roles and audiences can be drawn from the list "Perspectives on an STS Issue" provided on page 39 in Alberta Education's *STS Science Education: Unifying the Goals of Science Education* (esthetic, ecological, economic, emotional, ethical, legal, militaristic, mystical, political, scientific, social and technological). For a complete discussion, consult pages 30–43.

Choose a role and audience for the exercise, or have your students choose their own.

For example:				
	Topic	Role	Audience	Format
	photosynthesis	chloroplast	root of plant	appeal

Then choose a writing format for students to use, perhaps drawn from the list below.

Writing Formats

This is not an exhaustive list, only a starting point to get your mind working. All of these forms can be adapted for use in a science class.

adventure tale	instructions	rap (rhythmic chant popular in rock music)
advertisement	invitations	recipe
article	joke	report
autobiography	journal/diary	request
biblical passage	letter	resume
billboard	list	review
biography	logbook	riddle
book review	magazine	schedule
brochure	manual	script
case study	menu	slogan
children's book	message	song
comic	multiple-choice questions	story
crossword puzzle	myth	storyboard
editorial	newspaper	summary
epitaph	pamphlet	test
essay	photo-essay	tongue twister
fairy tale	poem	travelogue
greeting card	puns	want ads
headlines	quotations	worksheet

To create the RAFTS assignment, write a sentence tying together the role, audience, format, topic, together with a "strong verb" identifying the main purpose of the writing:

As a <u>(ROLE)</u>, write a <u>(FORMAT)</u> to <u>(AUDIENCE)</u>, <u>(STRONG VERB) ing</u> about <u>(TOPIC)</u>.

For example:

- As a chloroplast, write an appeal to the roots of your plant complaining about the lack of raw materials.
- As an amoeba, to the other pond residents, write an editorial in "The Pond Press" complaining about ____. (Science 10, Unit 2, No. 4)

Use RAFTS to make up quickie five- or 10-minute in-class writing exercises, or to develop essay assignment topics.

- As a tree, write a complaint to the Canfor Pulp and Paper Mill about your treatment in the paper process (Science 30, Unit 2, No. 3)
- As the mayor of Edmonton, write a reply to a citizen complaining about the foul taste of spring water, explaining the reasons for the taste. (Science 30, Unit 2, No. 1)
- Imagine a time in the 19th century you have just discovered ______________ and are trying to convince the National Geographic Society to fund further research.
- Pretend you are a skeptical scientist in the 19th century, attempting to disprove a discovery by your colleague.
- Imagine it is sometime in the 22nd century, when you as a scientist have just discovered that some understanding we now have about something is fundamentally wrong. Tell about your findings.
- Examine a "new improved version" of an actual product recently released by a company. Imagining yourself as the competitor, design and test an even more improved version.
- Create a mock public hearing in the classroom for an issue currently being debated by government. Various stakeholders identified ahead of time by the teacher must research and present their position through role play before the appointed committee.

Use RAFTS assignments when you want to tempt students to make new mental connections, or explore elements and applications of a concept that they may not have thought of through "regular" question-answer channels. Use RAFTS to make up quickie five- or 10-minute in-class writing exercises, or to develop essay assignment topics. Students can use the RAFTS formula to make up their own writing assignment. A pleasant side-effect of RAFTS assignments is the usually lively and interesting products. For further information and ideas, check *The Writing Process: Using the Word Processor* p. 27–29, or the *Science 14/24 Teacher Resource Manual*, p. 81.

2. Other Activities for the Portfolio

Following are more suggestions for writing assignments, speaking/listening or viewing activities that students might undertake to add to their portfolio. Many of these suggestions work partially from the RAFTS concept of having students adopt a different role, or address an audience other than the teacher, or use a format different from a traditional science report. In all of them, the student is being asked to use information about a particular scientific process, concept, phenomenon, principle, force or any other element you are teaching them in science:

- Make up a story about someone whose life was strongly affected by this particular element.
- Choose a particular element (e.g., Science 20, Unit 2, No. 2 a particular fossil, or No. 3 a particular glacier) and tell the story of this element since it first existed, as if you were telling it to a six-year-old.
- Tell the story in a "rap" song for a 12-year-old.
- As the element, tell a part of your own story that no human has yet discovered.
- Imagine you are a particular phenomenon or thing (a chromosome in a 40-year-old female, the heart of a dog, a rock from the Paleozoic era, a neutron in a nuclear weapon, etc.) and tell your story. Use words or pictures or both (create a play, story, collage, storyboard, comic strip, photo-essay, etc.) .
- Write a mystery story where this element is part of the key to the solution (e.g., The Foul Case of the Acid Bath Murder).
- Make up a love story in which the element is a central character.
- Make up a "fractured fairy tale," adapting an old tale, using scientific information they have learned.
- Tell a myth explaining how this element came to exist (as introduction to unit).
- Tell a science fiction or fantasy story showing a world where this element is being used in ways thought impossible today.
- Tell the story of what happened during a real lab experiment – but change the ending, if you like (narrating the discovery process).
- Relate in writing, or in pairs/small groups, an anecdote from personal experience illustrating the science principles/skills being learned.

- Make up a case study based on a problem that the element is creating. The teacher may need to remind students that a case study describes a specific real-life issue, giving enough background and detail for problem solvers to work with, and including brief portraits of the key players involved and their points of view. The teacher may want to select the most interesting case studies produced and assign them to small groups of students to solve, or have various small groups each develop a solution independently to the same case study, then compare and debate their solutions.
- Create a graphic model to represent new learning.
- Create a cartoon to humorously personify an organism being studied. Perhaps use professional examples like Gary Larson's *The Far Side* as models.
- Analyze influence of media on people's understanding of science issues. Or make generalizations about the prominence of certain science issues in the media at certain times.
- Analyze a government position on a particular issue affecting health, technology or the environment. Take into account factors like fiscal restraint, rights of various stakeholders, political considerations . Or debate the issue as scientists view it, opposed to the bureaucratic stance.
- Analyze and compare newspaper editorials on certain science issues, examining and evaluating authors' views, accuracy of information presented, simplification of information for lay audience, etc. You may find essays by David Suzuki, Carl Sagan, Isaac Asimov, Lewis Thomas, Rachel Carson and other scientists who write well in some of the authorized resources for senior high language arts.
- Analyze a case study of a science-technology-society issue, using science concepts learned. Material for case studies may be borrowed from current events, such as decisions being debated at government levels regarding the Al-Pac mill or the Oldman Dam. Have students research the case in groups, obtaining the necessary information from the media, government reports, interviews. Then have the group propose their recommended decision.
- Create a storyboard for a film to show a process or explain a concept for a particular audience.
- Dramatize a scientific concept or process, and present to elementary or junior high students.

- Analyze treatment of a science-technology-society issue in a feature film, noting its presentation, accuracy, viewpoint presented. Or analyze and evaluate extrapolation of current scientific knowledge to predict conditions and developments in a science fiction film.
- Analyze the image of science and scientists in media (in advertisements, on television, etc.).
- Research and analyze the construction of special effects for feature films. Students might use helpful publications such as *Cinefex* (a periodical available quarterly from Valley Printers, P.O. Box 20027, Riverside, California 92516).
- Analyze advertisements that use "scientific information" as support. Evaluate the accuracy of information presented, noting any important omissions and use of "weasel words". Or analyze advertisements making claims about a particular product, then design experiments to test these.
- Debate the scientific use of animals for product testing.
- Evaluate and compare "environmentally friendly" products. Or analyze advertisements for such products.
- Record process of a complex experiment by taking colour photos or slides, then arranging and presenting these as a photo–essay or documentary.

SAMPLE WRITING ASSIGNMENT BIOLOGY 30

- Write a lyric poem on any topic in Biology 30.
  e.g., focus on a particular organ, a particular organ system or the interaction of two systems.
- Minimum of 16 lines.
- Either 4-, 6- or 8- line stanzas possible.
- Choice of rhyming schemes.
  e.g., AB AB
  ABBA

A Biological Rhyme

Biology is a class where we learn about our body
From the cells of life to the human anatomy
From the parts of our eyes, to the marrow of our bones
How muscles behave in achieving good muscle tone.

The excretory system was very enlightening
but when I saw certain parts, I found them quite frightening
Dissection is cool, cutting organs is great, but touching and
handling them is something I hate.

The digestive system takes in foods that we eat,
And even has something for us to excrete,
Blood, corpuscles, neurons and capillaries,
words which broaden and enhance my vocabulary.

Inside my brain this course merrily flows,
with thoughts of Biochemistry or H_20,
Some words can't be found in an ordinary dictionary,
so I look in my text under a word called "Glossary."

Exams and tests are not a big thrill,
So usually before them my body feels ill,
I'll be very simple and yet quite discrete,
Biology is interesting and really quite neat.

From parts of the cell to the biological laws,
It's time for me to stop writing and hold all applause!

Richard Okolo
May 15, 1991

Sample Evaluation Scheme

English/Rhyme	-	3
Length	-	1
Clarity	-	2
Bio content	-	4
Creativity	-	9
		19/20 Well done!

The formal research project in science relies on a research process that is described at length in the Alberta Education document *Focus on Research.* This process involves planning, then retrieving and processing information, and finally sharing that information then evaluating the entire process. If students choose to share information through a written report, they engage in a writing process as well as a research process. The writing process dovetails into the information retrieval/processing part of research, then continues as students refine the communication of this research in written form. When science teachers understand this writing process and allow students time to go through it, the quality and clarity of the science report improves dramatically.

1. Writing Process Approach to Formal Writing

When students are preparing written reports, essays or other formal writing for an audience, they cannot usually spin out clear, concise, well-organized, properly punctuated prose when they first set pen to paper. The expectation by some students that this will happen is a frequent source of frustration. Writing is in fact a long and usually messy process. It varies remarkably for each individual, but the process often is generalized as follows:

Prewriting	Ideas percolate, are consolidated and clarified in the writer's mind. A purpose and audience for the writing are established. Initial planning occurs—putting the ideas into words and the words into some logical sequence. "Prewriting" happens in observation, discussions, thought, spontaneous writing, more thought, more writing, and so on. During research, the stages of planning, information retrieval and information processing are all part of prewriting. Prewriting usually continues after drafting has begun.
Drafting	The "writing out" of ideas begins. Usually a first draft is "revised" once or twice or many times as the writer reorganizes, rewords, deletes and adds ideas to draft succeeding drafts.
Editing	When the content is "set" and the writer is pleased with the shape, clarity and order of the piece, details are studied to polish the writing: spelling, punctuation, grammar, usage, tone, format, etc.

Lots of information is available in Alberta Education documents about helping students develop writing skills through understanding their writing process. See the list of references provided at the end of this chapter.

Ideas for Helping Students Improve Writing Skills in Senior High Science

- Allow students time in class to explore and shape their ideas for a formal report through talk, list-making, spontaneous writing, etc.
- Encourage revision by asking to see first and second drafts attached to final report.
- Allow time for revision in class: for instance, declare an early due date for first drafts, then have students work with partners or in small groups to read each other's piece and provide feedback. This process is called "conferencing" or "peer editing". Most of your students will have been taught what to do by their language arts teacher. Be sure to give them specific criteria and a structure for giving feedback. For further how-to information, check the list of references at the end of this chapter.
- Provide models of "good" student writing, perhaps using the overhead projector, to show students what you mean by clear descriptions of things observed, well-organized paragraphs, concise summaries and so on.
- Try not to grade all formal reports, paragraphs, etc. For example, you can have students submit all finished pieces but you only choose certain ones to mark. Or have all students prepare a lab report but only select one from each group to mark. Have students evaluate each other's writing. Small groups can assess a set of papers according to criteria you teach them. Students can evaluate their own writing for scientific and technological accuracy.

READING STRATEGIES FOR SCIENCE MATERIALS

Some of your students will not have many reading strategies to help them learn new science concepts through textual explanations. Consult the list of references at the end of this chapter for reading techniques for information texts. Some of the strategies explained in these resources include:

Headlines	Divide material into chunks, and form a headline to summarize the information in each chunk.
Outlines	Condense all the key ideas into a one-page outline, writing each as an appropriate heading.
Questions	Skim the material, then list all your questions about it. Read to find the answers to the questions.
Predicting	Skim titles, subheadings, pictures, graphics, opening and closing paragraphs, then predict content. Before and during reading, stop periodically to list predictions and hypotheses about the information being presented. Compare these with others. Compare them to information revealed later in the text. Or before reading, try spontaneously writing everything you know about the topic being presented and predict what new information you will learn.
Key Lines	Choose the most important lines. Justify and compare to others' choices.
Response	After reading, write spontaneously a personal response (see specific suggestions in the Writing to Learn section) or write questions you have about the reading.
PQ4R	Quickly *preview* or skim the material, then list *questions* that occur based on this skimming; then *read, reflect, recite* by answering questions, and finally *review*.

SPEAKING/LISTENING

Through talk, just as through writing, students process their learning. As they talk they sort out and clarify their learning, test their hypotheses, become aware of their associations, make connections between the new ideas and their past experiences and knowledge, and extend their understandings. Opportunities for small group discussion should therefore be frequent. Teacher-led discussion on occasion is valuable, but this approach severely limits the number of students who get a chance to verbally "chew through" the new concepts. Whole-group discussion is also not as "safe" a place as the small group to work verbally through half-formed ideas and ask questions.

Consult the list of references at the end of this chapter for speaking/listening activity ideas. Following are some brief summaries of ideas explained in these resources:

Role Play	Selected students in a discussion assume the point of view of a different person (e.g., in a small group debating an issue, each student might speak from the perspective of a different stakeholder).
Debate	Formal teams of two pairs, or informally in small groups. Students debate an issue posed as a resolution (e.g., be it resolved that fossil fuel consumption will be limited by household), using persuasive logic and researched support to present their opinions.
Jigsaw Groups	Example: Each small "home" group is given a different article to read and make sense of (e.g., listing key points and author's overall position). Then one person from each "home" group is sent to join a new "composite" group, another person from each is sent to make up the second "composite" group, and so on. In the "composite" groups, members in turn teach their new group the article they studied in their home group.
Fishbowl	Informal small group discussion in the centre of the rest of the class, who observe and assess. Stop periodically for class reflection/analysis of what's happening, insights revealed, etc., or stop to substitute a student from the observing group.
Seminar	Student "teaching" class through speech, slide-tape, display, dramatization, model or other presentation of concepts learned.

VIEWING

Viewing is considered a communication activity because we must view to read and to comprehend the non-verbal messages crucial to oral exchange. With the explosion of media now being used in science classrooms, as well as in treatment of science issues in the world, critical viewing is an important skill to help students develop. Consult the list of references at the end of this chapter for helpful ideas for integrating television, film, radio and print media into your science classes.

One approach is to analyze critically the presentation of a science issue or concept on film or television, separating facts from opinions, examining method of presentation and selection of information, assessing use of the entertainment factor to make science "palatable" for the lay audience, the persuasive techniques used, etc.

Try a focus on form. Students can examine the visual presentation, the effects of sound, music, lighting, movement, special effects, camera angle, editing, colour, composition, line and symbols to present phenomena in the natural world, or make a statement about a scientific issue. Or examine form in newspaper presentations. How is the eye directed to certain stories? What prominence is science given in overall context? How are science stories juxtaposed with others and with ads, what viewpoint is expressed editorially and what is the comparative frequency of science-issue editorials? How are headings and graphics, and other devices for simplifying the message, used?

In all viewing, it's important to help students stand back critically from the viewed messages you bring into the classroom.

In all viewing, it's important to help students stand back critically from the viewed messages you bring into the classroom. You help mediate their response – through discussion and guided reflection, prompting them to really *see* from different perspectives. Spend time before each viewed presentation, providing context and purposes for the viewing, helping students to focus on certain elements. After viewing, allow time for them to write about their responses and observations, and to discuss/compare their analyses with others.

Another aspect of "viewing" activities is actually creative construction, having students develop their own visual presentation of a concept, process, phenomenon on or opinion on an issue. Possible forms for such a presentation include storyboard (a "blueprint" for a film – a series of drawings depicting the sequence of camera shots, with corresponding dialogue written underneath), comic strip, poster, advertisement, collage, photo-essay, computer graphics, display, slide-tape presentation, video production, board game or bulletin board.

RECOMMENDED RESOURCES FOR LANGUAGE ACTIVITIES IN SCIENCE

* Ordering information for the following resources can be found in the Resources Section of this document.

Alberta Education. 1990. *Diagnostic Learning and Communication Processes Program: Handbook 1 Integrating Evaluation and Instruction and Handbook: Four Diagnostic Teaching Units Science.* Student Evaluation and Records Branch. A set of checklists to help teachers systematically diagnose students' level of thinking/learning.

Alberta Education. 1990. *Focus on Research: A Guide to Developing Students' Research Skills.* Curriculum Branch, Alberta Education, 1990. A must-read handbook for teachers having students engage in research projects, providing a description of the "research process," strategies for helping students through the process, evaluation methods and lots of practical examples.

Alberta Education. 1991. *Senior High Language Arts Teacher Resource Manual.* Curriculum Branch.

Alberta Education. 1989. *Senior High Social Studies 10–13, 20–23 and 30–33 TRM.* Curriculum Branch.

> Both these TRMs are easily available, and contain helpful sections on speaking/listening and writing activities (including marking "keys" for grading student writing and presentations).

Alberta Education. 1986. *Teaching and Evaluating Reading in Senior High School.* Contains valuable strategies for helping students read more effectively, with sections on reading for information that will be of interest to science teachers.

Alberta Education. 1982. *Viewing in Secondary Language Arts.* Available in most schools. Presents many activity ideas using film, television and pictures – all easily adaptable to science classes.

Alberta Education. 1989. *The Writing Process Using the Word Processor: Inservice Leader's Reference Manual.* A large binder full of suggestions for writing assignments, with good sections on learning logs, using RAFTS and on evaluating student writing.

Clarke, Judy, Wideman, Ron, and Susan Eadie. 1989. *Together We Learn*. Toronto: Prentice-Hall. An authorized resource for senior high that presents very practical collaborative learning strategies (ways to use and evaluate small group discussion).

Elbow, Peter. 1981. *Writing with Power: Techniques for Mastering the Writing Process*. New York: Oxford University Press. Explains every aspect of the writing process in a very readable way that makes sense. An excellent chapter on spontaneous writing (which he calls "freewriting," showing its applications in teaching, learning, business, etc.).

Jeroski, Sharon, et al. 1990. *Speak for Yourself: Listening, Thinking, Speaking*. Toronto: Nelson Canada. Contains many practical suggestions for using debates, small and large group discussions, speeches and presentations, and other learning activities in senior high classes.

Kirby, Dan and Tom Liner. 1988. *Inside Out: Developmental Strategies for Teaching Writing*. 2nd ed. Portsmouth, N.H.: Boynton/Cook Publishers. Excellent resource of practical writing activities that can be used in science classes. Also presents good help for evaluating students' writing and managing the marking load.

Ontario Ministry of Education. 1989. *Media Literacy Resource Guide*. Very practical, very interesting handbook filled with activity ideas using film, television, advertisements and other media for senior high classes (cross-curricular approach, so activities are adaptable to any subject). Also presents compact summaries of the elements to analyze critically in each medium.

EFFECTIVE USE OF A RESEARCH PROCESS

by Teddy Moline

"6 – 7,000 scientific articles are written every day. Science and technology information doubles every 5½ years and soon will double every 20 months."

"If you are in your 40's, half of the world's scientific knowledge has been discovered and documented since you left high school."

Quotes such as these emphasize that students of this generation face a more bewildering array of information than has previously existed – for both quality and quantity of information have changed. Developing the skills and strategies to deal effectively with information will prepare students to function fully in society and will contribute to their appreciation of learning as a lifelong process.

Developing the skills and strategies to deal effectively with information will prepare students to function fully in society and will contribute to their appreciation of learning as a lifelong process.

Locating background information on a scientific topic, issue, prediction, or hypothesis is a prerequisite to, and an integral component of scientific experimentation. All scientific developments require that the scientist locates, analyzes, processes, digests, and applies related information prior to experimentation.

Scientists require effective literature research strategies and skills in order to access this information. They must be well-read and knowledgeable about sources of current scientific information: science networks, databases and other periodic updates, and have information handling, experimental, and theoretical skills, if unnecessary duplication and erroneous data gathering are to be avoided. Scientists do not invent without finding out what has already been done. In some cases, because adequate previous research in an area has not occurred, unnecessary time, effort and monies are expended to perform an experiment which has already been well-documented and confirmed.

An effective literature research process for acquiring and analyzing background information mirrors the scientific research process. Students with effective literature research strategies and skills are applying scientific reasoning and demonstrating transference of scientific skills.

The Continuum of Research Skills and Strategies

The goal of a comprehensive research process is to enable students to transfer the skills and strategies that they learn in any subject area, to all types of curriculum-based research—scientific, historical, empirical, action, etc., and to many situations in everyday life. Students need many opportunities to practise and improve their research strategies and skills, and, to be meaningful, the research process must be related to students' previous knowledge/experience and to their studies.

Focus on Research: A Guide to Developing Students' Research Skills (1990) provides a sample 'research process' approach to developing research skills. This research model presents a developmental approach to research and contains both a continuum of research skills and strategies and a continuum of levels of research, introductory to advanced.

The Continuum of Research Skills and Strategies

The continuum of research skills and strategies encompasses five stages:

Stage 1: Planning
- determining initial topic, method and end-result

Stage 2: Information Retrieval
- assessment of resources

Stage 3: Information Processing
- synthesizing, analyzing, and evaluating information

Stage 4: Information Sharing
- presenting the final product

Stage 5: Evaluation
- reflecting on the complete process and identifying changes and transferable situations

Each stage is composed of skills and strategies which empower students to handle information efficiently. The continuum is cumulative, and students acquire expanded skills and strategies while working through the stages. At times, however, only one aspect of the research stages or skills for a particular activity will be practised, and there should always be considerable movement back and forth amongst the stages.

Different models of research processes may involve more steps and/or different terms, but three essential concepts must be included:

- begin research by relating it to students' past experiences/knowledge,
- then anticipate and plan for research, and
- conclude by validating and extrapolating strategies to use in other situations.

At times, only one aspect of the research stages or skills for a particular activity will be practised, and there should always be considerable movement back and forth amongst the stages.

The following table demonstrates the close correlation between the *Focus on Research* process and scientific models.

Focus on Research Model Correlated to Various Models Associated with Science Teaching

Focus on Research	Science Inquiry Model	Society/Decision Inquiry Model	Problem-Solving Model	General Learner Expectations
Planning	Questioning/ Proposing Ideas/ Designing Experiments	Identifying Issue/ Alternatives	Planning	Generating
Information Retrieval	Gathering Evidence	Researching	Collecting Data	Data collecting
Information Processing	Processing Evidence	Reflecting and Deciding	Analyzing Data	Organizing, Analyzing, Integrating
Information Sharing/ Evaluation	Interpreting Evidence	Taking Action/ Evaluating	Explaining	Evaluating

The Continuum of Levels of Research

In *Focus on Learning*, the continuum of levels research, introductory to advanced, indicates that students will progress, as they experience more research activities, from teacher-directed (dependent) learning to student-directed (independent) learning.

The two ends of the research level continuum, introductory to advanced, are not grade-labelled. Students of any age may attain the skills and strategies identified in the introductory or advanced level with only the level of complexity differing as the student progresses through school.

IMPLEMENTATION

Developing and implementing research activities works efficiently when science teachers cooperatively plan with the teacher-librarian. It is recommended that in cases where a teacher-librarian is unavailable due to low enrollment, a cooperatively planned research project could be worked out between classroom teachers.

CONTACTS

Many ideas and suggestions for integrating research skills and strategies into science curricula are found in science, education, and school library periodicals. As well, research sessions are offered at most teachers' conventions and specialist council conferences. Many jurisdictions have a school library consultant and science consultant who can suggest further ideas.

Additional contacts for ideas for teaching research strategies include:

- Learning Resources Council Executive, ATA
- Science Council Executive, ATA
- *The Book Book* (ATA publication) in each school
- Alberta Education staff and others involved in the production of this teacher resource manual and in *Focus on Research: A Guide to Developing Students' Research Skills*.

USE OF PERIODICALS IN THE CLASSROOM

by Desiree Hackman

The teaching of science within STS learning contexts lends itself to the extensive use in the classroom of articles from magazines and newspapers. In order to have a ready supply of articles available, it is recommended that a hanging file system be established.

- Teacher Preparation
  - Establish hanging files of articles on topics related to the curriculum, such as: ozone depletion, greenhouse effect, acidic deposition and deforestation.
  - Consider collecting a series of articles on a particular issue; local articles where relevant; interest-provoking articles to use as lead-in or follow-up.
  - Use as material for individual or small group assignments or as enrichment material for students who finish daily activities early.
  - Consider developing focusing questions and clear, simple assignments based on an article or series of articles clipped.

- Classroom Activities
  - Use articles to develop critical thinking related to science-oriented environmental issues. (For additional background see Professional Development Inservice Module 10: *Environmental Connections in the New Science Programs.*)
  - Have students develop collages on themes like energy, matter, change.
  - Introduce and practice the SQ3R reading technique, leading to article summary or question assignments. (For additional background on SQ3R reading technique see Assessment and Evaluation Section page.)
  - Initiate scrapbook projects calling for collection of articles with specific purposes in mind; e.g., technology in the news.
  - Develop oral presentation assignments which include a visual display component which includes articles and/or pictures.

- Bulletin boards on various themes can be assembled by students or teachers:
  - technologies grouped into such categories as desalination, alternative energy sources, disposal of hazardous wastes
  - daily news clippings following a specified issue
  - career possibilities in science and/or technology.

COPYRIGHT

Under the current copyright laws, teachers require written permission to copy class sets of articles from periodicals or newspapers. Some periodicals release copyright permission for special circumstances. For example, *Environment Views* Alberta Environment states

> "Permission to reproduce any part of this publication for commercial purposes should be obtained by writing the address below. Reproduction for other purposes should credit this publication."

The original article may be displayed on a bulletin board or be laminated for circulation in the classroom.

Consider purchasing class sets of newspapers with relevant articles or science sections. The newspapers could be split up and used in cooperation with language arts and social studies teachers. The whole paper can be used in search and clip activities designed to accomplish curricular objectives, particularly the STS connection component.

Both *The Edmonton Journal* and *Calgary Herald* have Newspapers in Education Programs. Newspapers are provided at a special education rate based on bulk purchase orders of 100 or more. Complementary educational resource packages such as "*Our Fragile Future*" and "*Give Earth a Chance*" are provided with these orders

The Edmonton Journal and *Calgary Herald* have provided the following information regarding their policies and procedures:

The Edmonton Journal

- All material written by *Edmonton Journal* staff writers may be duplicated in class sets.
- Any article not written by an *Edmonton Journal* writer would require written permission from the service agency concerned; e.g., CP, Reuters, King Features, Knight Rider Newspapers. Addresses for these various service agencies can be obtained from public library reference sections.
- Extra copies of daily newspapers are kept for short periods and may be available on request from the Circulation Department. There is usually a nominal charge.

- For additional information, contact:

  Newspaper in Education Program Coordinator
  The Edmonton Journal
  Box 2421
  Edmonton, Alberta, T5J 2S6
  Phone: 429-5175

Calgary Herald

- No material may be duplicated for class sets without written permission.
- Extra copies of daily newspapers are available on request, while supplies last, free of charge. Special editions or high demand papers usually have a charge.

Newspaper in Education Program Coordinator
Calgary Herald
P.O. Box 2400, Station M
Calgary, Alberta, T2P 0W8
Phone: 235–7149

Teachers are encouraged to contact their local newspaper representatives to determine the particular policy regarding the use of newspaper articles in the classroom.

Articles from magazines or other periodicals may also be valuable for use in the classroom.

However, permission must be obtained from the owner of copyright material before a resource can be duplicated for normal classroom use.

For permission to reprint copyrighted material from other periodicals, a sample "request for permission" letter and a copyright permission form has been provided in the Appendix.

SAMPLE "Request for Permission" Letter

May 31, 1991

Discover
3 Park Avenue
New York, NY 10016

Dear Sir/Madam:

Re: Request for Permission to Reproduce Material

On behalf of Sturgeon Composite High School, I am writing to request permission to make copies of Andrew C. Revkin's "Endless Summer: Living with the Greenhouse Effect" from *Discover*, to which our school library currently subscribes. The article will be used by students in my classes for educational purposes only and would not be sold.

I have attached two copies of a Copyright Permission Form providing information regarding the article to be reproduced.

I would appreciate it if you could return a copy of the form along with your letter of permission.

If you do not have the authority to grant permission to reprint the article in question, would you please forward this request to the appropriate person.

Thank you for your assistance.

Sincerely,

Desiree Hackman
Science Teacher
Sturgeon Composite High School

Attachments

COPYRIGHT PERMISSION FORM

School Jurisdiction: ____________________ School: ____________________

Address: ____

____

____

Permission is requested to reproduce the following copyrighted materials published by your company.

Title: ____

Writer(s): ____________________ Publisher: ____________________

Date of Publication: ____________________

☐ Article(s): ____________________ ☐ Part of Article(s): ____________________

Number of copies to be made: ____________________

Use of Materials

☐ classroom use (specify) ____________________

☐ special circumstances ____

Reprint Permission Requested ☐ Yes ☐ No

Date required: ____________________ Duration of permission: ____________________

All reproduced works will contain a statement of permission to reproduce and the name of the agency permitting reproduction.

Permission is hereby granted to *School/school division* to arrange for reproduction of the above material as defined in the attached letter.

☐ credit statement ____

____

☐ at the following charge ____________________ ☐ at no charge

☐ reprint permission granted ☐ Yes ☐ No

☐ under the following conditions: ____

____

AUTHORIZED BY ____________________

COMPANY ____________________ DATE ____________________

Adapted from Copyright Clearance Policy Procedures Statement, October 1990
Student Programs and Evaluation Division, Alberta Education

AN STS CONTEXT

by Bob Ritter

OVERVIEW

An STS approach to science attempts to make the learning of science personally relevant and socially meaningful. Scientific knowledge is linked with technological innovation, the manner in which students experience science, in order to close the gap between classroom study and life experience. By placing science within a social context, it is hoped that students gain a better appreciation for the impact of science and technology on society. Equally important, is a view of science as a social activity. Science and the construction of scientific knowledge are greatly affected by society.

Scientific knowledge is linked with technological innovation, the manner in which students experience science, in order to close the gap between classroom study and life experience.

Alberta Education's *Secondary Education in Alberta* (1985) Policy Statement indicates that the best preparation for students to anticipate and shape the future is a broad general education with emphasis on critical and creative thinking, communication, personal development, science and technology and an understanding of the community. Clearly, the boundaries of science have been extended to meet the changing needs of our students. The horizons of presenting scientific knowledge have been extended beyond developing an understanding of basic science concepts and developing science process skills into the realms of technology and society. Not surprisingly, the broadening of learner expectations must be accompanied by new learning and teaching strategies.

CHANGING ROLE OF TEACHER AND STUDENT

The STS approach increases the demands on the teacher. The linking of science content to technological application, and the presentation of science within a social context require a greater information base. The broader focus can be accommodated if the teacher assumes the role of facilitator of learning, as opposed to the director of learning. The facilitator model places the teacher in a position to help students find answers to their questions. The technological problem-solving aspect of the STS approach promotes lateral thinking skills. Multiple approaches can be tried and later evaluated. Learning is no longer perceived as a series of activities that enables the student to arrive at preset answers. The teacher will often present the problem, but in many situations students become actively involved in developing a procedure. Student-directed investigations emphasize on cooperative learning strategies, which place the teacher, as investigator, within the research group.

The teacher will often present the problem, but in many situations students become actively involved in developing a procedure.

Changing Role of Student

Reproductive Thinker	Autonomous Thinker
• reproducing knowledge	• creating and discovering knowledge
• passive recipient	• active decision maker
• convergent, rule-abiding	• divergent, steps outside of rules to create original ideas
• information narrowly focused	• information broadly focused and interrelated
• one right answer	• multiple solutions
• external evaluation	• mistakes are learning device
• individualistic, competitive	• collaborative

Changing Role of Teacher

Directive Thinking	Facilitative Thinking
• provisions of knowledge	• construction of knowledge
• disseminator	• mediator, collaborator
• content focus	• process focus
• information narrowly focused	• information broadly focused and interrelated
• general student assessment based on common standards	• assessment of student as an individual learner
• common instruction	• accommodation of learner differences

Taken from *Teaching Thinking, Enhancing Learning*, Curriculum Branch, Alberta Education, 1990, p. 11.

LEARNING ACTIVITIES

In an era where information is created far faster than it can be acquired. a shift from memorizing information toward the development of thinking skills will occur.

Research suggests that a greater variety of learning activities better enables teachers to accommodate different learning styles. Subgroups identified as less likely to enroll in science programs may be included, should new learning activities be employed. In addition to lectures, small group problem-solving sessions, demonstrations, and laboratory activities, the STS approach makes for a variety of simulations including: case studies, interactive debates, and role-playing scenarios available to science students.

STS strategies call for students to become active participants in the learning process. In an era where information is created far faster than it can be acquired, a shift from memorizing information toward the development of thinking skills will occur. Students will be empowered to organize information in ways that enable them to understand it or identify what they do not understand. No longer 'll the repetition of formulas or memorization of definitions characterize science classes. Students will be asked to explain their thinking; the correct answer will no longer be considered enough. Students will be asked to provide their own solutions to problems, and to evaluate divergent approaches. Problem-solving and decision-making processes will occur within a social sphere where students are encouraged to make predictions, develop hypotheses, collect and organize data, and draw conclusions through collaboration. A list of STS learning activities is provided below:

Clues can be provided throughout the demonstration to draw student attention to important aspects of the activity.

1. **Demonstrations**

   This type of activity provides an opportunity to relate theory to experiential learning. Unlike the laboratory experiments, which provide opportunities for small group discussion, demonstrations are designed for larger groups. Basic concepts can often be introduced by the demonstration because of the common experience. Individual groups do not work in isolation. Clues can be provided throughout the demonstration to draw student attention to important aspects of the activity. All too often, some of the more subtle observations can be overlooked by the novice investigator. Should the teacher assume a role of collaborator rather than that of director, students may be asked to perform demonstrations for their peers. Units that have a number of demonstrations are ideal for cooperative learning .

2. **Lab Activities**

   a) Structured laboratory activities – teacher-directed.
   In this strategy, the teacher sets the goals, explains the rules and often models the procedure. The students apply the skill and reflect upon the experience. Much of the learning is directed toward the acquisition of specific knowledge or the verification of theory. Defined correct answers are often sought.

   b) Student-designed laboratory activities – teacher as facilitator
   A spectrum of open-ended student-designed laboratory experiments can be provided. Due to the complexity of certain procedures, some teacher mediation or intervention is often required. A variety of strategies is possible:

      - The student-designed laboratory activities often follow structured labs and provide an extension of the original investigation. A general procedure is often applied for a different situation.

- Teacher provides a problem and a general procedure. The students are asked to set up an experiment to study the problem. Students should be asked to identify the independent and dependent variables. The establishment of a control should be promoted.
- Students ask questions which lead to investigation. The teacher works as a collaborative researcher. Concept mapping and brainstorming sessions are used to define the problem, collect information on the topic, identify a research methodology, and begin the research. The direction of the investigation is clearly on data collection and interpretation of data rather than on arriving at previously known answers. Most investigations raise more questions! Focus of the lesson is on the open-ended nature of the scientific endeavour.

3. Brainstorming Sessions

Brainstorming sessions allow students to generate a wide variety of ideas on a topic or theme.

Brainstorming sessions allow students to generate a wide variety of ideas on a topic or theme. Hitchhiking of ideas is promoted. The value and diversity of a large number of ideas can be discussed. For example, students may be asked to list various concerns of establishing a waste management plant in their community or list ways in which they could reduce their energy consumption. Generally, a recorder is appointed by the group to collect ideas. One or two students are often selected to report ideas to other groups. Small group discussions may precede or follow an activity such as a reading, a lab activity, a demonstration, or a case study. The smallgroup problem-solving session begins with a problem that is either social or technological. The brainstorming session can lead to decision-making strategies. Ideally, judgment should be withheld during the decision-making process, or students should be prepared to change opinions as additional information is collected.

4. Simulations

By placing the learner in an active role, simulations provide a model for studying complex physical or social interactions.

Simulations present an artificial problem, event, situation or object that replicates reality but removes the possibility of injury or risk during the activity. By placing the learner in an active role, simulations provide a model for studying complex physical or social interactions. Unlike many authentic situations, simulations can be modified to meet classroom limitations. Because the simulation makes the event manageable, simulations enable teachers to plan linkages between acquired knowledge and skills, and student activities. Simulations can be grouped into three large groups: (1) social simulations, (2) person to computer, and (3) computer to computer. Only social simulations will be explored for STS classrooms in this section of the teacher resource manual. The purpose of simulations is to:

- Motivate learners
- Present diverse opinions and the rationale for each of the opinions
- Sensitize individuals to another person's concerns or world view
- Reduce complex problems or situations to critical issues by developing analytical processes
- Prepare students to meet conflicting roles and present opportunities for decision making
- Foster specific attitudes and behaviours, by promoting self-reflection.

a) Case Study

The case study provides the learner with an opportunity to analyze and interpret scientific data. Case studies are often used in place of laboratory investigations. Like computer simulations, the case study enables the student to gain experience in areas in which conventional laboratory work is difficult. Case studies can provide essential background information for future discussions. Most case studies are designed for individual or small group work. Some examples of potential case studies are provided:

Like computer simulations, the case study enables the student to gain experience in areas in which conventional laboratory work is difficult.

- Longitudinal succession studies provide the student with an opportunity to examine trends over a number of years.
- By examining models of cell membrane and binding sites, case studies on pathogens such as HIV provide students with an opportunity to study potentially dangerous viruses.
- Environmental impact studies, such as how acid rain has destroyed the Black Forest of Germany, provide actual examples of cause and effect relationships.
- Case studies of scientists doing research provide a window for students to view the scientific endeavour. The example of cold fusion and the subsequent rejection of the theories of Pons and Lieschman is one of many of the examples.

Role playing often provides an avenue for presenting biased opinions, which may or may not agree with the opinions of the students.

Scientists with divergent interpretations of data or scientists who use different paradigms to describe natural events can enter into discourse during a role-playing scenario.

b) Role-playing scenario

Role-playing formats are designed to teach selected social processes, such as negotiating, bargaining, compromise, and sensitivity, which govern human relations. The simulations often present an issue and character profiles so that the consequences of collective actions may be charted. Role playing often provides an avenue for presenting biased opinions, which may or may not agree with the opinions of the students. Most important, it will introduce divergent points of view and allow the student an opportunity to analyze and respond to them. It is hoped that students gain an appreciation for the reason why individuals hold divergent points of view. Ideally, the role-playing scenario should foster critical–thinking skills, while promoting tolerance of alternative world views. All simulations have rules which govern human interaction. Regardless of the roles which are assumed, certain behaviours are promoted while others are not allowed. Some sample role-playing scenarios are provided below:

- By assuming the role of different people within a town or city, students respond to the prospects of a landfill site being placed in their community. Because each group lives in a particular area, arguments are drafted which protect specific interest groups. Students assigned as town councilors or aldermen are challenged with the task of resolving the issue.
- Opposition between those who believe in using pesticide sprays, systemic sprays, and those who believe in biological control is voiced during a public forum. Each interest group presents sound and logical arguments, but each provides a different view of what constitutes a more desirable place to live.
- Scientists with divergent interpretations of data or scientists who use different paradigms to describe natural events can enter into discourse during a role-playing scenario. For example, the particle theory of light can be proposed by a student role-playing Sir Isaac Newton, while the wave theory of light is proposed by another student role-playing Christian Huygens. Each scientist shows how the theory is able to explain natural phenomena. The remaining students in the class are asked to resolve the controversy.

c) Interactive Debate

While role-playing scenarios provide a wide diversity of opinions, debates are most effective at presenting divergent opinions and attitudes. Unlike the role-playing scenario, where students are given particular interests, the debate usually draws on their own positions on science-related social issues. "Pro" and "con" formats can be used to illustrate the main points within the debate as a dialectic. While the scenario is often make-believe, the debate provides a forum for personal commentary. Because students often hold debated opinions with greater personal conviction, the debate must be structured in a manner in which sensitivity to various points of view is accepted, if not agreed with. Some possible topics are provided for classroom debate:

- The prospects of determining screening human DNA is frightening. Who will have access to the information? Will the genetic screening be mandatory? Could anyone be harmed if the information was released?
- Should individuals who continue to drink alcohol or smoke, after physicians have warned them that their health is in danger, be considered for heart or liver transplants?
- Should laws that govern sulphur dioxide and nitrous oxide emissions be made more stringent? What are suitable emission standards?

Because students often hold debated opinions with greater personal conviction. the debate must be structured in a manner in which sensitivity to various points of view is accepted, if not agreed with.

5. Topic Research or Career Exploration Investigation

A series of questions that requires various forms of library research can be used to direct students during the activity. Both individual and cooperative learning techniques can be used. The investigation promotes lifelong learning skills. Sample research topics are presented below:

- Report on the feasibility of a perpetual motion machine.
- Comment on the usefulness of solar batteries.
- Investigate a career in medical laboratory technology. Where do they work; what are the career prospects; what academic qualifications are required; what educational routes are available?

LEARNING CONTEXTS

Three learning contexts, Nature of Science, Science and Technology, and Social Issues of Science are found within science programs in Alberta. Nature of science encompasses the foundation of knowledge in natural sciences and the development of an understanding of the manner in which science attempts to explain the natural world. The second component attempts to develop an understanding of the relationship between science and technology. Scientific knowledge is used to explain technological devices. Technology is presented as a means of solving practical problems, which include both techniques and products. The third component, the role of science and technology in socia' issues, attempts to establish an understanding of the impact of society on science and technology, and conversely, the impact of science and technology on society.

Nature of Science

Scientific knowledge should be presented as tentative, and ever-evolving, rather than as irrefutable truths.

Nature of science refers to the manner in which scientific knowledge is constructed. Process skills development such as hypothesis formation, designing an experiment, organization of data, interpretation of data, and the formation of conclusions, encircles one aspect of the nature of science. The use of scientific laws, the formulation of scientific theories, theory modification, and the limitations of scientific knowledge are also found under the umbrella of nature of science. Scientific knowledge should be presented as tentative, and ever-evolving, rather than as irrefutable truths.

Nature of Science Sample Lesson 1: A Discrepant Event

Time

Approximately 40 minutes is required to complete the procedure; however, more time should be allotted for the completion of the write-up.

Prior Knowledge

Students will be able to:
- define kinetic and potential energy
- explain how energy can change forms

Curriculum Fit

Science 10, Unit IV: Energy and Change

Motivation and Set

Teacher presents the following challenge:

Things are not always what they appear to be. The experiment below is designed to stimulate your thinking. All of the statements are true, but one or more may appear to be falsified by the experiment.

- Newton's First Law of Motion states that objects will continue at rest or in motion as long as no unbalanced force acts on the objects.
- Inertia is the tendency of an object to continue what it is doing.
- Newton's Second Law of Motion states that if an unbalanced force is applied to an object, the object will accelerate at a rate that varies with the mass of an object.
- Weight is the measure of gravitational force that Earth exerts on an object.
- Work is done by exerting a force on a body over a distance. The body must move in the direction of the force applied.

Instructional Activities

Teacher Activities	Student Activities
• Teacher divides students into groups and assigns laboratory. (This activity is designed as a teacher-directed activity. By removing the clues, such as using a ruler to measure the height of the cone, this activity can be presented as a teacher-facilitated activity.)	• Students perform laboratory and begin write-up.

Objective

To explain a discrepant event.

Materials

2 sealer jars with good sealing lids
Books to support the ramp
Wide ramp
Tape measure
Water

Procedure

1. Stack a pile of books on the floor and place one end of a ramp on the books.

2. Fill one sealer jar approximately half-full of water. Leave the other jar empty.

Diagram to be added

3. Lift the sealer jars to the top of the ramp and release them so that the jars roll down the ramp together.

Observation

Sealer jar	Speed	Distance (m)
Empty	Rolls slower	Rolls farther
Water in jar	Rolls faster	Does not roll far

Questions

1. Which jar has the greater potential energy at the top of the ramp? Explain your answer.

   2 marks: The jar filled with water contains the greater potential energy. It takes the greater amount of energy to place the jar with greater mass on top of the ramp.

2. Why does the empty jar roll farther?

   2 marks: Friction between the water and the glass jar makes the jar slow down. Although the jar is set in motion, the water remains at the base of the jar. A new section of the glass cylinder comes in contact with the jar as it spins. The contact causes friction. Energy is lost to friction; therefore, the jar will not move as far.

3. Predict what will happen if the jar that is half-full of water is completely filled with water. Test your hypothesis.

   1 mark: Any prediction is correct until tested.

4. Explain what you observed for the jar filled with water.

   3 marks: When completely filled with water, the jar travelled farther. The water moved along with the glass. Because the water completely filled the glass jar, it acted like a single, solid object. Friction was reduced because the water was set in motion along with the glass. The glass also had greater mass and therefore, greater potential energy. The greater potential energy was transferred to the jar as kinetic energy. This caused the jar to move faster. Greater energy was needed to set the jar on the ramp and greater output energy caused the glass to travel farther.

Connection of Nature of Science to Technology

The investigation provides some of the scientific knowledge required for students to understand how potential energy can be used by machines to do work. The importance of measuring energy and the determination of the efficiency of energy conversions by various technologies can be examined. Some students will want to know why the jars travel at different speeds. Even the type of fluid placed in the jars will affect velocity; however, such explanations require a greater knowledge of physics. Changes in velocity must be examined by considering the position of the mass, rather than the quantity of mass. The investigation provides an example of hypothesis formation and hypothesis testing.

Connection of Nature of Science With Social Issues

The investigation provides a springboard for the initiation of discussions on various topics that deal with energy conservation. For example, the conversion of chemical energy by automobiles may be examined with an eye on energy conservation. The importance of driving a car with great acceleration may be examined in the light of the efficiency of energy conversion and energy conservation.

Evaluation

- Critical-thinking skills are emphasized in this assignment. Students must be given time to synthesize and apply information.
- Answers in this section can be expressed in a variety of ways. Partial marks should be awarded for original answers, even if the answers are not totally correct. The answer must demonstrate a logical progression of scientific thought. A suggested marking guide is provided. See answers to questions.

Nature of Science Sample Lesson 2: Monitoring Water Quality (Teacher as facilitator)

Time

Set aside a full class period to brainstorm lab design.
A full day should be set aside for the collection of data.

Prior Knowledge

Students will be able to:

- explain why sewage treatment plants are important
- identify and describe problems associated with water pollution
- explain why BOD, Biological Oxygen Demand, reading provides an indicator of water quality
- explain and demonstrate how changes in acidity can be detected by pH indicators.

Curriculum Fit

Science 30, Unit 2: Chemistry in the Environment

Motivation and Set

Teacher questions the effectiveness of the sewage treatment plant in the city or town. Students are asked to brainstorm the importance of a properly functioning sewage treatment plant. All answers are written on board.

Instructional Activities

Teacher Activities	Student Activities
• Teacher divides students into groups and explains how coliform tubes allow you to measure fecal bacteria levels in water. Teacher assigns laboratory.	• Students identify problem and ask the following questions: 1. What do I already know about the topic? 2. What do I want to learn about it? 3. Where do I begin looking?
• Teacher, as facilitator, seeks to help groups arrive at an experimental design.	• Students perform research and begin laboratory activity during the next scheduled class.
• Teacher collects information from different groups regarding prospective sites for study.	• Class chooses site for field trip to monitor water samples.

Objective

To determine the environmental impact of sewage treatment on water resources in your community.

Background Information

The coliform culture tube contains lactose sugar and a pH indicator. The lactose sugar will act as a growth medium for fecal bacteria, should any bacteria be present. As the bacteria oxidize the sugar, they produce carbon dioxide gas which forms some carbonic acid when combined with water. The carbonic acid causes the solution to become acidic and the indicator changes from a purple colour to yellow.

Materials

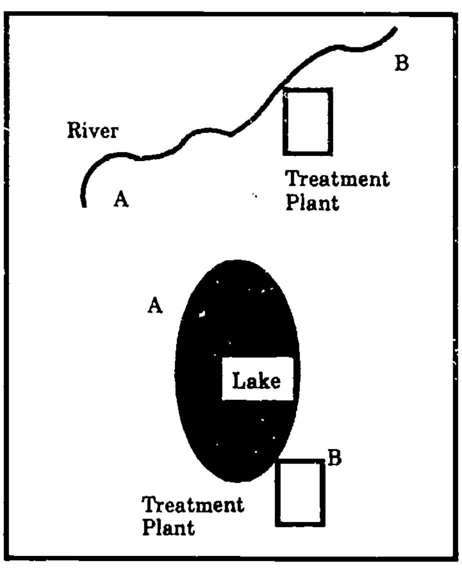
Map of city or town
Coliform culture tubes
2 medicine droppers

Procedure

1. Determine the location of the sewage treatment plant in your locale. Select a safe field station upstream from the sewage treatment plant and another downstream from the treatment plant.

   Draw a map locating the sewage treatment plant and test sites. A sample is provided below.

   2 marks: Answers will vary. Assign one mark for the presentation of the map and one mark for locating appropriate test sites.



If the sewage treatment plant in your community releases treated water into a lake, choose a site that is close to the treatment plant and another site that is a maximum distance away from the plant.

2. With a medicine dropper, add 20 mL of water from site A to one of the coliform culture tubes. Close the culture tube and label it with the correct site and the time of the test. Store the tube in a warm location.

   Caution: Do not open the culture tubes once filled with water samples.

3. Repeat the procedure for site B. Remember to label the culture tube with time, date and location.

4. Observe the culture tubes 24 hours after collection. A colour change from purple to yellow in the first 24 hours indicates that the sample is not fit for swimming.

5. Check your samples once a day for the next three days and record any colour change.

   Prepare a data table and record your results.

   Caution: Return the culture tubes to your teacher. Culture tubes must be autoclaved to destroy the microbes before disposal.

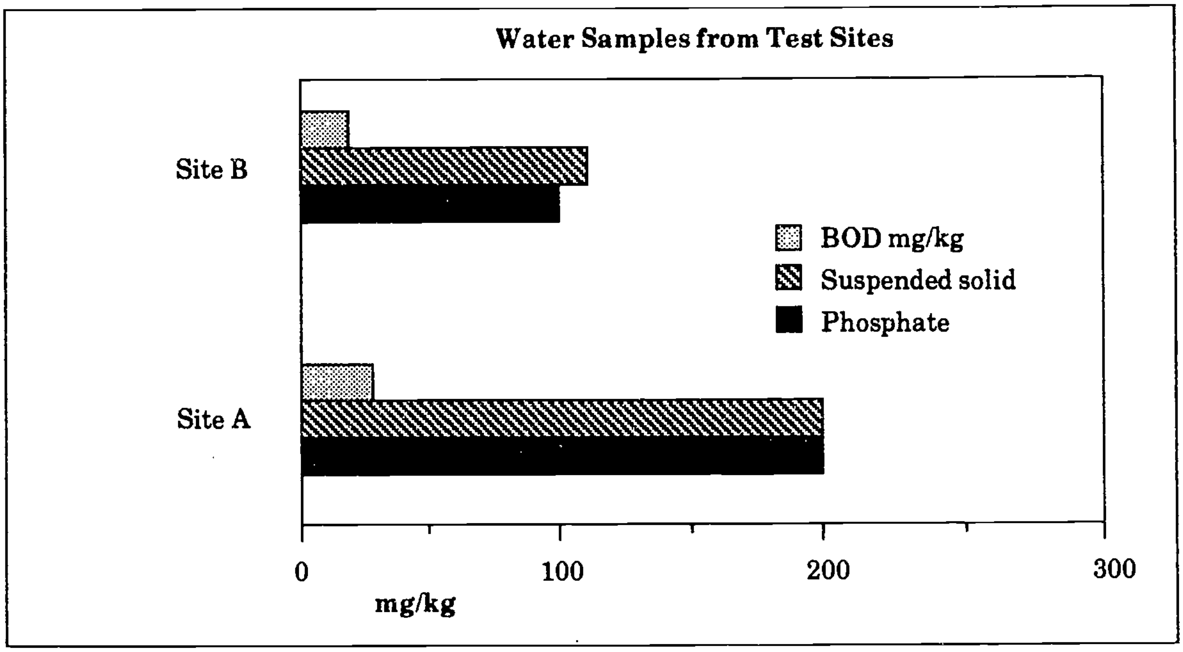
Answers will vary.

Questions

1. Which sample had the most bacteria? How did you arrive at your conclusion? 1 mark: Answers will vary. The student should choose the sample that turns yellow faster. Check prediction with data.

2. If the sample nearer the sewage treatment facility had the greater number of microbes, does that mean that the sewage treatment facility must be to blame? Give your reasons. 2 marks: Answer: No, other factors might be identified. Assign one mark for other factor, e.g., runoff from cattle, or see page from underground pollutants.

3. The data provided below was taken from two different sites. Use the data provided to determine whether or not the treatment plant is doing its job. Sample A was taken downstream from the treatment plant. Sample B was taken upstream from he treatment plant.



3 marks: It would appear that the treatment plant is not doing a great job. The low BOD indicates high bacteria levels and many organic nutrients remain in the effluent. The higher than normal levels of phosphates indicate that the phosphates have not been removed during tertiary processing. The total suspended solids are also higher than in the sample before the treatment plant, indicating insufficient settling and filtration of the sewage.

4. What problems do heavy rainfalls create for water treatment facilities?

   2 marks: The heavy rainfall will fill the settling ponds or tanks and cause runoff of the raw sewage.

5. Many sewage treatment facilities are not capable of removing heavy metals like mercury from the water. Indicate what problems are posed by returning heavy metals with the treated effluent.

   2 marks: Heavy metals act as poisons. They accumulate in the tissues of the body.

Articulation of Nature of Science With Technology

The investigation begins with a nature of science focus by providing students with an opportunity to collect, organize and interpret data. The focus of the investigation soon moves toward evaluating sewage treatment technology. Because some sewage treatment plants in Alberta do not employ tertiary treatment processes, the investigation leads students to investigate the effectiveness of different treatment processes.

The investigation provides a springboard for the discussion of various environmental and health issues associated with sewage treatment.

Articulation of Nature of Science With Social Issues

The investigation provides a springboard for the discussion of various environmental and health issues associated with sewage treatment. The importance of proper sewage treatment can lead students to assess priorities set by governing bodies while fostering an appreciation for diversity of opinions expressed by the various interest groups.

Evaluation

- Critic l-thinking skills are emphasized in this assignment. Students must be given time to synthesize and apply information.
- Answers in this section can be expressed in a variety of ways. Partial marks should be awarded for original answers, even if the answers are not totally correct. The answer must demonstrate a logical progression of scientific thought. A suggested marking guide is provided. See answers to questions.

1. Coliform culture tubes can be purchased from biological supply houses at very low expense.

2. Students should be directed to use a new medicine dropper for each sample taken. Medicine droppers, ideally, should be sterilized before use, but a good washing will suffice for the purposes of this lab.

3. Once water samples have been added to the culture tubes, students should be warned never to open the culture tubes.

4. Culture tubes and nutrient solution should be placed in an autoclave and heated at 120°C for 20 minutes before disposal.

The initial focus of this lesson is on technology. Technology is presented as a means of solving practical problems which include both techniques and artifacts. Technological problem-solving strategies are employed. Students often discover that scientific knowledge is required to solve technological problems. In the sample activity provided below, an understanding of distillation enables the student to understand how the solar still works.

Students often discover that scientific knowledge is required to solve technological problems.

Science and Technology Sample Lesson:
Using Sunlight to Separate Salt From Water

Time

Approximately 10 minutes are required to complete the brainstorming session during the motivation and set, and 20 minutes are required to complete the experimental set-up. By leaving the solar still set up for one day, dramatic results can be collected.

Prior Knowledge

Students will be able to:
- Describe how energy comes from the sun.
- Explain how solar energy can be used by technological devices to do work

Curriculum Fit

Motivation and Set

Teacher Activities	Student Activities
• Small group brainstorming groups are arranged. Usually six students per brainstorming group. Students are asked to list various technological devices that use solar power.	• Group recorder is appointed. Students list various devices and place names on the board.

Instructional Activities

Teacher Activities	Student Activities
• Teacher asks brainstorming groups to form lab groups. Usually, three students per lab group.	• Students read background information (see p. 17) and begin laboratory. Results are gathered 24 hours later.
• Teacher provides summary application at the end of the lab and encourages student discussion.	• Students consider survival value of solar still.
• Option: Should the teacher wish to present the activity in a less structured format, students can be given the initial design for the solar still, but may be asked to improve upon the design.	• Option: Students come up with their own designs for a solar still. Stills are constructed. Students derive a scheme to evaluate stills. Evaluation may be based on the amount and purity of the water collected.
• Option: Teacher, as an investigator, works collaboratively with students.	• Option: Students are encouraged to critique each other's designs.

Objectives

To separate water from salt in a solar still.

Background Information

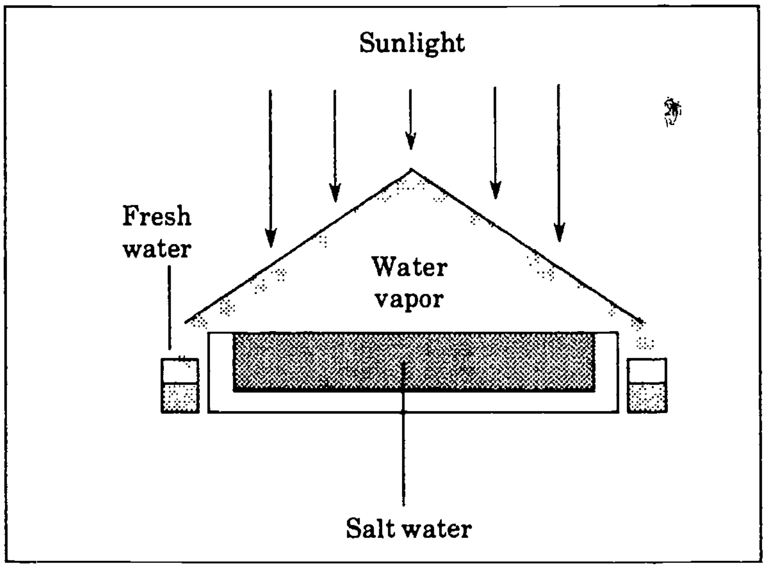
About 70% of the surface of our planet is water. However, the vast majority of the earth's water cannot be consumed. It is contaminated with either pollutants or salt. The planet's supply of fresh water is dwindling. The oceans of the world provide a vast source of water, which could be used for irrigation, manufacturing, and even consumption, if enough of the salt could be removed.

We know how to remove the salt. When salt water boils, the water vaporizes, leaving only the salt. This process, called distillation, removes the salt from water. Water changes from a gas to a liquid at 100°C, but salt remains as a solid. Water and salt are separated because salt and water have different boiling points. If the water vapor is cooled, it returns to a liquid form once again, and if the cooling occurs in a separate chamber the water will remain fresh.

Distillation is a process by which impurities can be separated by heating. The separation occurs because different materials display different boiling temperatures.

Although the technique is well known, water stills are not common. In order to bring large quantities of water to 100°C, a great amount of energy must be added. Conventional distillation processes that utilize fossil fuels or wood become a very expensive technology when used to heat large amounts of water.

Solar energy, however, makes the technology cost-effective. We do not have to pay for sunlight energy. The principle behind solar distillation is a simple one. Large amounts of water are collected in shallow tanks or ditches. The tanks are covered by plates of glass or plastic. As the heat from the sun is absorbed by the bottom of the tanks the temperature of the water begins to rise. Eventually, the water undergoes a phase change and becomes a gas. The water vapor, being lighter than the water, moves up toward the covering glass, which is cooler than the warmed liquid. The cooler glass causes the water vapor to condense (return to liquid). The water that has condensed along the glass can then be collected.



The above diagram on shows a solar still. The sunlight energy enters the glass pyramid and strikes the tank holding the salt water. Some of the sunlight energy is absorbed, and the rest is reflected toward the glass. But this energy is not lost. Remember the greenhouse effect. The reflected ultraviolet wavelengths are trapped by the glass. This causes an increase in air and water temperatures.

The water vapor condenses as it moves away from heated liquid. The diagram shows the condensed liquid moving down the sides of the glass and into a container.

The world's first large solar still was constructed in 1874, in the Chilean desert. The still provided water for mine workers and burros at a potash mine at Las Salinas, where the only accessible water was too salty for consumption. The still covered an area of 4 608 m^2 , and produced 22 800 L of drinkable water every day. The solar still was dismantled in 1914 when fresh water was piped into the area.

Solar stills are functioning today, especially in the sunny, dry climates of the world. Australia and Israel have gained world recognition with some of their large projects.

Materials

Large mixing bowl	Plastic wrap
Elastic band	Small rock
Salt and water	Drinking cup

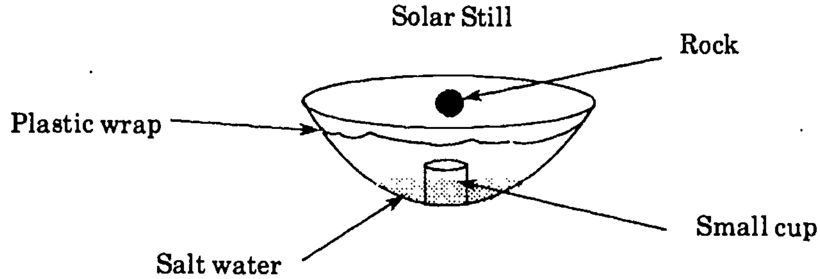
Procedure

1. Place a cup inside a large mixing bowl. Fill the mixing bowl with water until it rises to about 1/2 the height of the cup. Note that none of the water should go inside of the cup.

2. Mix a small quantity of salt with the water in the mixing bowl. Taste the water. If it doesn't taste salty, add more salt.

3. Cover the top of the mixing bowl with plastic sandwich wrap, and secure the wrap with an elastic band.

Solar Still



4. Position a small rock on the plastic wrap, and place the still in the sun. Do not allow the plastic wrap to touch the cup. (If it does, adjust the plastic wrap and select a smaller rock.) Place the still near a window and gather data 24 hours later.

   What function did the rock serve?

5. Check the small cup for water.

   How did water get into the small cup?

6. Taste the water in the small cup.

   Was the water salty?

Teacher-Directed Summary

There is little water available in the desert, but any place that can support plant life must have some water. The roots of the cactus extend well below the surface soils to the ground water.

By digging a deep hole and covering it with a sheet of plastic you can collect some of the water in a cup placed in the centre of the depression. A rock should be placed on top of the plastic sheet to help direct the collected water into the cup. A company sells a sun survival kit that contains a shovel, plastic sheet, plastic cup, stakes, and an instruction book.

Connection of Technology to Nature of Science

The investigation begins with a technology focus by providing students with an opportunity to construct a technological device. Scientific process skills are soon integrated within the activity as students collect, organize and interpret data to assess their technological device. An understanding of energy conversion, intermolecular forces, and radiant energy provides a basis for understanding the technology.

Connection of Technology to Social Issues

The investigation provides a springboard for various environmental issues associated with the feasibility of using solar energy as a non-polluting alternative source of energy. The importance of maintaining adequate fresh water supplies can also be approached from this discussion.

Evaluation

- Technological problem-solving skills are emphasized in this assignment. Students can be encouraged to try different types of bowls with different liners (such as aluminum foil) to improve the still.

- Answers in this section can be expressed in a variety of ways. Partial marks should be awarded for original answers, even if the answers are not totally correct. The answer must demonstrate a logical progression of scientific thought. A suggested marking guide is provided. See answers to questions.

Social Issues of Science

Sample Lesson: Should the Oldman River Dam Be Built?

Time

Allow at least one class period for students to gather and view research materials. A second class period should be set aside for the debate.

Prior Knowledge

Students should be able to:

- Describe how land forms can be changed. (Glaciation, wind/water erosion, earthquakes, volcanic activity, etc.)

Curriculum Fit

Science 30, Unit IV Energy and the Environment

Motivation and Set

Teacher Activities	Student Activities
• Teacher asks students to form small brainstorming groups of about six students. Teacher shows students a picture of a beaver and asks them to list some ways in which the beaver will change the environment.	• Students list ways in which the beaver changes the environment.
• Environmental impacts listed on the board. Students are encouraged to identify each of the impacts as either positive or negative. Do not define positive or negative for them.	• Students make lists and provide their reasons.

Instructional Activities

Teacher Activities	Student Activities
• Teacher directs students to background information on the Oldman River Dam.	• Students select the resource or resources they wish to use in preparing for the debate. See background information.
• This assignment can be done as either a debate or a position paper. The pro and con points are designed to get you started. They are not complete arguments. Although both sides of the conflict present rational arguments, each group works from a different set of priorities. The two groups are said to have different world views. The "pro" and "con" positions are designed to act as a springboard to get the discussion going. Many other issues are hidden within these points, and many others are yet to be presented.	• Students are given the opportunity to sign up for either the debate or the term paper. Students who believe the Oldman Dam project should continue, sign up for the "pro" argument. Those who are opposed take up the "con" position. Students select a chairperson and organize arguments for the debate.
• Your evaluation will be determined according to the manner in which you present your argument and according to research that you have completed.	• Students provide an evaluation for the debate.

(See controversial issue section of the teacher resource manual for further direction about implementing the debate.)

Objective

To share views on the environmental, social, and economic impact that the Oldman Dam will have on communities in south-eastern Alberta.

Background Information

Suggested references are provided below:

- Public Hearings on the Management of the Water Resources Within the Oldman River Basin. Environment Council of Alberta, 2100 College Plaza, Tower 3, 8215–112 Street, Edmonton, Alberta, T6G 2M4.
- *Monograph on Comprehensive River Basin Planning*, Ottawa,ON: Environment Canada.

- View the TV Ontario Video *H_2Overview*, BPN 230004. The videotape presents a futurist's look at fresh water supplies in North America. The program examines health risks from polluted water in the Great Lakes.
- View the video *Water in Alberta: The Living Flow* BPN272701 and BPN272702. The video was developed by Alberta Environment in conjunction with ACCESS Network. The first program, "Interconnections", views the state of water resources in Alberta, while the second program, "Complexities", provides an outline of the ways in which water is managed in Alberta.

The Debate

The Issue: Building a dam on the Oldman River is worthwhile.

PRO	CON
1. The Oldman River will help farmers in one of the arid parts of the province. It has been estimated that a water reservoir created by the dam will irrigate between 40 000 and 80 000 hectares of farm land. A great number of jobs will also be created by the project.	1. Business will increase while the dam is being built, but it will quickly decline once the project has been completed. The quick rise may actually hurt business, because it will be followed by a sharp fall. The dam maintenance will also place added burdens on taxpayers. Dams are expensive.
2. A small number of wild plants may be destroyed as the reservoir fills, but the loss is small when compared with the gains in domestic agriculture. The farms that will be consumed by the flooding will more than be made up for by the increased production of the other farms that will have a reliable source of water for irrigation.	2. The dam will flood an estimated 2 500 hectares of excellent farmland. It will also destroy natural wildlife breeding sites in the process. The peregrine and merlin falcon both nest in the area and are on the endangered species list.

On August 9, 1990 the Government of Alberta decided to build the dam at the Three Rivers site on the Oldman River. Do you think the dam should be built?

Articulation of Social Issues with Nature of Science

Although the initial focus of the study is on a social issue, students will soon come to realize that scientific knowledge (an understanding of land forms and ecological succession), is the key to understanding the social issue. The social issue will either provide a direct application of previously learned information or provide a context in which the learning or review becomes personally meaningful. The manner in which scientific data is gathered and the manner in which the data is interpreted is called into question during this study. Most important, the limitations of science become somewhat clearer during the discussion of the controversial issue.

Articulation of Social Issues with Science and Technology

Although the initial focus of the study is on a social issue, students will soon come to realize how social issues require an understanding of alternative technological resolutions.

Evaluation

Paper

The marks are awarded according to three categories. A maximum of 5 marks can be obtained in each category. A mark of 1 indicates minimal effort, while a 3 is an average mark. A 5 indicates exceptional effort.

Marking Scheme

Category	1	2	3	4	5
1. Research, content					
2. Quality of expression, grammar, spelling, word usage					
3. Organization					

Debate

The marks are awarded according to three categories. A maximum of 5 marks can be obtained in each category. A mark of 1 indicates minimal effort, while a 3 is an average mark. A 5 indicates exceptional effort.

Marking Scheme

Category	1	2	3	4	5
1. Research, provides evidence of further reading					
2. Quality of expression, grammar, word usage, logic used, arguments supported					
3. Progression of the argument, willingness to listen to other views, alternative viewpoints considered and addressed (group mark)					

CONTROVERSIAL ISSUES

by Bob Ritter

Alberta Education Controversial Issues Policy (1991) is provided in Appendix A

BENEFITS OF CONTROVERSIAL ISSUES IN CLASSROOMS

The application of science through technology can give rise to controversial issues. Controversy arises when groups with competing world views draw divergent conclusions about the impact of science and technology on society.

An approach that uses controversial issues enables students to make connections between what they have learned in science classes and the manner in which they experience science in everyday life. Research indicates that discussing controversial issues has been used to motivate students in reading and research tasks related to the issue. The discussion also provides an avenue for the enhancement of a wide variety of intellectual skills. Conflict resolution skills ensure that students learn to think critically, to reason, to argue logically, to devise answers that are supported by evidence, and to reflect upon their thinking. The development of conflict resolution skills coincides with the development of attitudes needed to allow students to broaden and refine their opinions and value commitments. Group resolution techniques encourage students to listen to each other and to recognize the difference between rejecting an idea and rejecting a person. Students also have the opportunity to learn about themselves and others as they work through value conflicts found within controversial issues.

Group resolution techniques encourage students to listen to each other and to recognize the difference between rejecting an idea and rejecting a person.

What Controversial Issues Should Be Used in Classrooms?

Although there is no single answer to this potential dilemma, the following points may provide some guidance:

- Consider the maturity and intellectual level of the students. The parameters of an issue may have to be defined to focus discussion on the issue. Some issues may not be understood by younger students.
- Do students consider the issue to be important?
- Does the issue support curriculum? Issues that do not have a direct relationship with the knowledge presented in the science course will confuse rather than enhance student learning.

- Is the issue one that can be treated within the time allocated? Simplistic overviews of issues can be avoided by allowing sufficient time for research and brainstorming.
- Can the issue be properly researched? Students should be encouraged to move beyond emotional responses.
- Does the teacher feel comfortable talking about the issue?
- Will the issue clash with community standards or subject a particular subgroup of students to ridicule?

Controversial Issues and the Nature of Science

Most research answers some questions but raises many others. Research is rarely terminal.

Students unaccustomed to viewing science and technology from a social context may reduce controversial issues to "good science" versus "poor science". For these students, science provides unequivocal answers. Any discrepancy points to "poor science". The key to developing an understanding of why experts, when analyzing scientific data, occasionally arrive at different conclusions, is grounded within an understanding of the nature of science. Science does not provide absolute truths but offers an approach for interpreting nature. Most research answers some questions but raises many others. Research is rarely terminal. For example, the recent debate between dentists and some toxicologists on the use of mercury fillings arises because scientific research is unable to provide all of the answers. The dichotomy is provided by a sample debate below. Although the initial discussion is rooted in a technological application, the discussion soon becomes directed toward the manner in which scientific research is conducted.

- How is toxicity measured?
- Do standards, which establish acceptable levels of toxicity, ensure that no one will ever become ill?
- How subjective are standards?
- Why are tests that define acceptable standards of mercury in humans not performed on humans?
- How will differences in pH of saliva, certain diets, and the grinding of teeth affect the rate at which mercury is released from the fillings?
- How many variables are left uncontrolled?

Nature of Science Social Issue: Mercury Fillings and Kidney Disease

How many times have you read that something is harmful? Some studies, for example those on coffee, often provide different conclusions. Have you ever experienced frustration in attempting to evaluate divergent interpretations presented by two groups of experts? The frustration expressed by most people often arises because of a misunderstanding of how research is conducted and data are decoded. Science is rarely as definite as most people believe. Answers are challenged. The challenge may not even be directed at research methodology, but at interpretation of research data. Many experiments in science merely indicate that further research is needed. The following research issue provides an example.

Experiments by Dr. Murray Vimy and Dr. Fritz Lorscheider, researchers from the University of Calgary Medical School, point out concerns over using silver fillings for teeth. Studies carried out on sheep indicate that half of their kidneys became dysfunctional within 30 days after 12 fillings were placed in their mouths. The results were published in the prestigious journal, *The Physiologist*, in August 1990, and were presented to the American Physiology Society in October 1990. Vimy, a Calgary dentist, believes that the amalgam fillings should be banned. The two researchers believe that mercury in the amalgam filling leaks into the bloodstream. The mercury is believed to affect the kidney.

Point	Counterpoint
Mercury has long been cited as problematic, yet dentists continue to use it for fillings.	Not every researcher agrees with the interpretations of Dr. Vimy and Dr. Lorscheider. It should be remembered that their studies were not carried out on humans. Amalgam fillings have been used for many years on humans, many of whom have properly functioning kidneys.
Alternative fillings are possible. Dentists may use gold, ceramic, and different resins instead of the controversial amalgam. The use of amalgam should be suspended until further research can be conducted.	How do we know that the replacements are less harmful? In an interview given to the *Calgary Herald* newspaper, Dr. Bill Long, past-president of the Calgary and District Dental Society, has indicated that the fillings are safe. He went on to indicate that replacement materials are not as good.

Dispute about the effects of coffee on humans, the impact of the greenhouse effect on global warming or the effective use of superconductors to provide electrical energy are but a few of the topics that demonstrate a diversity of scientific viewpoints. Students who lack a fundamental understanding of the processes of science often express frustration because a single answer cannot be provided by science. For these students, science is a means of providing answers, rather than a way of asking questions and testing hypotheses.

Controversial work on vitamin C or cold fusion experiments provide a springboard for understanding scientific discourse. Importantly, students gain an understanding of the nature of science by becoming involved in science-related discussions. Even bogus studies of polywater and Lamarkian evolution have value in that they stimulated scientific thinking and further research.

THE LIMITATIONS OF SCIENCE

Key to understanding any science-related social issue is an ability to identify components of the issue that directly involve the application or interpretation of scientific knowledge.

Scientific knowledge, like other forms of knowledge, is socially constructed, and therefore subject to the foibles and blunders inherent within any human activity. It is important that students recognize that scientific theories change or are modified as additional information is provided or as social views are altered. Scientific truths are tentative. Science is only one way of knowing, and, even more important, science only answers some questions. A scientist cannot shuttle a scientific argument into the realm of theology or philosophy and remain credible. Eugenics used the cloak of science to propagate racist notions concerning intelligence and the value of different races to society. Races cannot be compared, nor can human value be determined by science. The very issues identified by eugenics are not ones of science.

Key to understanding any science-related social issue is an ability to identify components of the issue that directly involve the application or interpretation of scientific knowledge. An understanding of where science begins and where science ends is vital to assessing the impact of pulp mills on a river system or assessing the effects of using various pesticides in specific ecosystems.

The assessment of water quality is a difficult one. The release of dioxins and other toxins may not create observable transmutations in an ecosystem. However, can we be sure that long–term problems will be manifest immediately? Changes in the genetic code may not likely be expressed in adults because genes that control development are no longer active. Similarly, time is required before the multiplier effect of toxins can be traced through a food chain. Basic questions of science help define the issue. What clues indicate that dioxins and other toxins are harmful? How is it possible to be sure that environmental changes can be related to the pulp mill? Would environmental modelling experiments, with carefully controlled variables, really indicate what would happen in a natural ecosystem?

CONTROVERSIAL ISSUES AND TECHNOLOGY

The assessment of a better life requires a fundamental understanding of scientific principles and the potentials and limitations of a particular technology. For example, a meaningful discussion of the impact of acid rain cannot occur if students do not understand that as the pH in a lake falls from 5.4 to 4.4, the level of acidity has increased tenfold not onefold. Similarly, discussions of the effectiveness of taller smokestacks or the use of scrubbers in smokestacks to reduce acid rain requires an understanding of how taller smokestacks dilute sulphur dioxide and how harmful chemicals are neutralized in scrubbers. An evaluation of the technological device requires an understanding of gas laws, basic chemical reactions, and the interactions and interrelationships of biotic and abiotic things within an ecosystem. A technological innovation may be questioned on economic grounds, ethics, or on the basis of the limitations of the technology. A prerequisite to assessing the controversial issue is an understanding of:

A technological innovation may be questioned on economic grounds, ethics, or on the basis of the limitations of the technology.

- how the technology works
- the limitations of the technology
- alternative technological resolutions of the problem.

Technology-Related Controversial Issue Evaluating Medical Technology

Background Information

The controversial issue below addresses the use of artificial hearts. To date, artificial heart transplants have not been successful.

The artificial heart replaces the pumping actions of both the right and left ventricles. The artificial heart is attached to the natural blood vessels. Rubber balloon-like diaphragms are connected to an air pump outside of the body. As the balloons are filled with air, they push blood out of the artificial ventricles into the arteries. The pump then removes air from the artificial ventricles and blood moves into the chambers from the veins. Artificial heart valves prevent blood in the arteries from being drawn back into the ventricles, much like that of a real heart valve.

The artificial heart, unlike a transplanted heart, has several advantages. The first is that a donor is not required. Heart tissue cannot be preserved for long periods of time once removed from the donor's body. The artificial heart, unlike the transplanted heart, requires no tissue cross-matching. Not every donor's heart is appropriate for every recipient.

One of the disadvantages centres on economic considerations. The artificial heart was once thought to be less expensive than a traditional heart transplant, but the figures are now being called into question. A number of problems have surfaced.

Skeptics believe that the artificial heart was not properly tested before it was used on human subjects. Early tests on calves revealed problems controlling infections. A second problem, that of calcium deposits in the artificial heart, raised even more concern. Two hypotheses were put forth to answer the problems with calcium. The first suggestion centered around the fact that calves were still growing, and higher concentrations of calcium were in their blood. The second suggestion focused on the compatibility between the blood and the mechanical equipment. The infection and calcium problems were not settled before the artificial heart was placed in Barney Clark, a 61-year-old dentist. Dr. Clark suffered from cardiomyopathy, a disease characterized by an irreversible degeneration of heart muscle. Without the operation, Barney Clark was sure to die.

During the operation, a broken ventricle caused air to bubble into the lungs. A second major operation followed, but this time Barney suffered a seizure, and a broken heart valve led to a third operation. The third operation also presented difficulties. Barney Clark experienced serious nosebleeds and a fourth operation was needed. Following this operation, a weakened Barney Clark experienced disorientation, and later he developed pneumonia and then kidney failure. One hundred and twelve days after the first operation, Barney Clark died.

The Issue

Why should money be spent on the artificial heart rather than on finding ways to prevent disease?

Why should money be spent on the artificial heart rather than on finding ways to prevent disease? With unlimited resources there would be no question about where the money is spent. Artificial heart research is worthwhile, but it takes money from preventative programs. Preventative measures can save more lives than artificial heart technology, but preventative medicine lacks the dramatic appeal of heart surgery. An education program that is based on a list of "do's and don'ts" has little public appeal. Research in preventative medicine rarely captures headlines. Preventative medicine does not create heroes. Heart surgeons and medical engineers are good candidates for champions. Listed below are some additional points for consideration.

The Limitations of Technology

Point	Counterpoint
Barney Clark was sure to die without the artificial heart. The artificial heart provided a chance in the same manner that early heart transplants provided a chance.	A Florida firefighter, who had applied for an artificial heart eight months before Barney Clark, was turned down by the artificial heart transplant team. The firefighter outlived Barney Clark.
Barney Clark helped advance artificial heart technology so that others may live.	Was the transplant done to secure finances? Shortly after the heart transplant, Kolff Medical, the firm that makes the Jarvik 7 heart, was able to raise 20 million dollars.

Technology is often described in terms of applied science; but technology is much more. Technology is the purposeful and controlled use of knowledge, materials, and natural phenomena to solve practical problems. For a technology to be successful it not only has to be scientifically sound, but economically feasible and socially acceptable.

For a technology to be successful it not only has to be scientifically sound, but economically feasible and socially acceptable.

Most people experience science through technology. Although scientific knowledge enables us to understand technology, scientific knowledge alone cannot be used to evaluate technology. For example, the prospects of drastically reducing carbon dioxide emissions by eliminating the combustion of fossil fuels would be met with violent opposition. Although solar and nuclear energy technologies provide alternative sources of energy, the cost of conversion would be prohibitive. The prospects of global warming due to the greenhouse effect have been linked to elevated carbon dioxide levels, but science cannot provide all of the answers needed to assess the controversial issue. Scientific knowledge merely provides evidence to show cause-and-effect relationships between the burning of fossil fuels and increasing carbon dioxide levels in the atmosphere. Science shows that carbon dioxide is released when carbon compounds undergo combustion. Science also shows that carbon dioxide in the atmosphere traps infrared light, a form of solar energy. However, the issue is not exclusively a scientific one. Science is not designed to weigh the economic plight of individuals who work in the oil industry against the need for a sustainable environment. Any assessment of the difficulties created for individuals who work in jobs related to fossil fuels must acknowledge the benefit of other groups. Science, along with economics, aesthetics, religion, and sociology helps identify some of the pertinent information.

Science, along with economics. aesthetics, religion, and sociology helps identify some of the pertinent information.

Research on atomic structure has lead to the development of nuclear energy, new chemicals, superconductors, and an atomic bomb. It is important to note that technology cannot decide what research should be done and what research should be rejected. Ethics operate by different guidelines and, even more important, are designed to solve different problems. Although the decision-making process extends beyond the boundaries of science and technology, the assessment of the issue requires an understanding of the technology. Students who do understand what the technology can do and what it cannot do may fall into the trap of presenting scenarios that are unlikely to be viable for either scientific or economic reasons.

DECISION-MAKING PROCESS

Students are often asked to suspend judgment until all of the facts are gathered; however, most people tend to personalize controversial issues rather quickly. In that most technology is directed toward specific interest groups, judgments are often linked to the benefits supplied to a specific group. Therefore, it is recommended that students be allowed to evaluate an issue as they begin to gather data. First impressions are not always negative, but students should be open to changing their first impressions.

Most issue identification begins with an egocentric understanding of the issue.

Most issue identification begins with an egocentric understanding of the issue. Sharing the research findings with individuals who hold a similar viewpoint may provide a wider base for understanding the issue, and formulating or evaluating different resolutions. During the final stage, opposing groups present divergent perspectives, and challenge findings and conclusions. The following may help students gain a better understanding of the issue and the problems presented by different resolutions.

1. Issue is identified and individual research begins.

    - Student seeks resolution.
    - Student evaluates resolution from a personal point of view.
    - Trade-offs are considered.

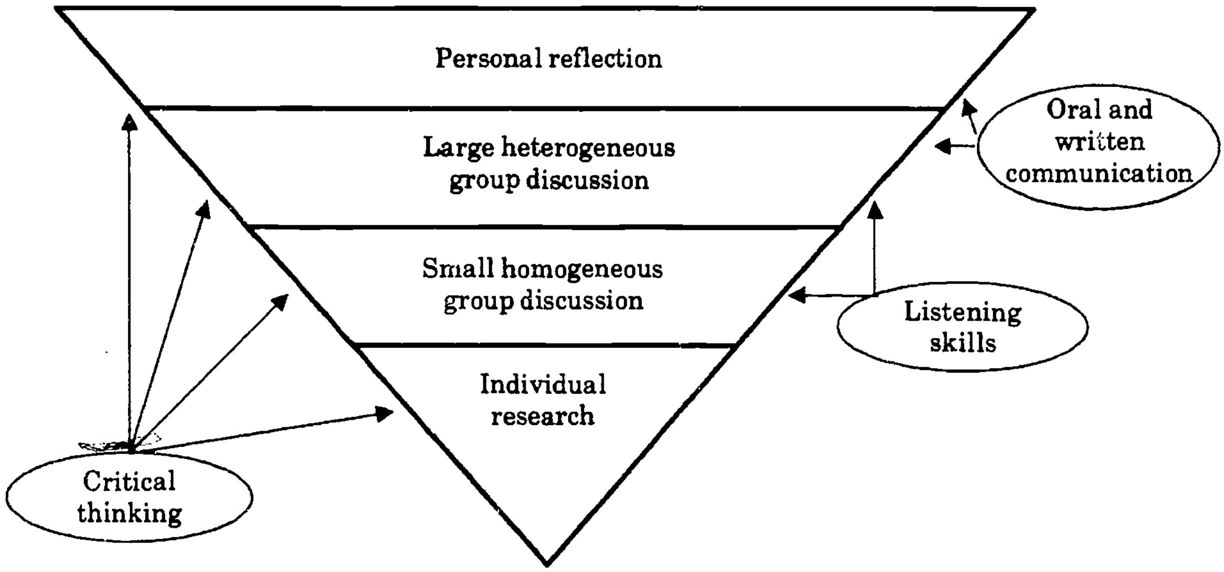
2. Students are organized into small groups composed of individuals who hold similar opinions

    - Group attempts to identify assumptions that they have used in formulating their opinions.
    - Group identifies its own set of values and priorities.
    - Group attempts to identify political influences, economic influences, cultural influences and religious influences.

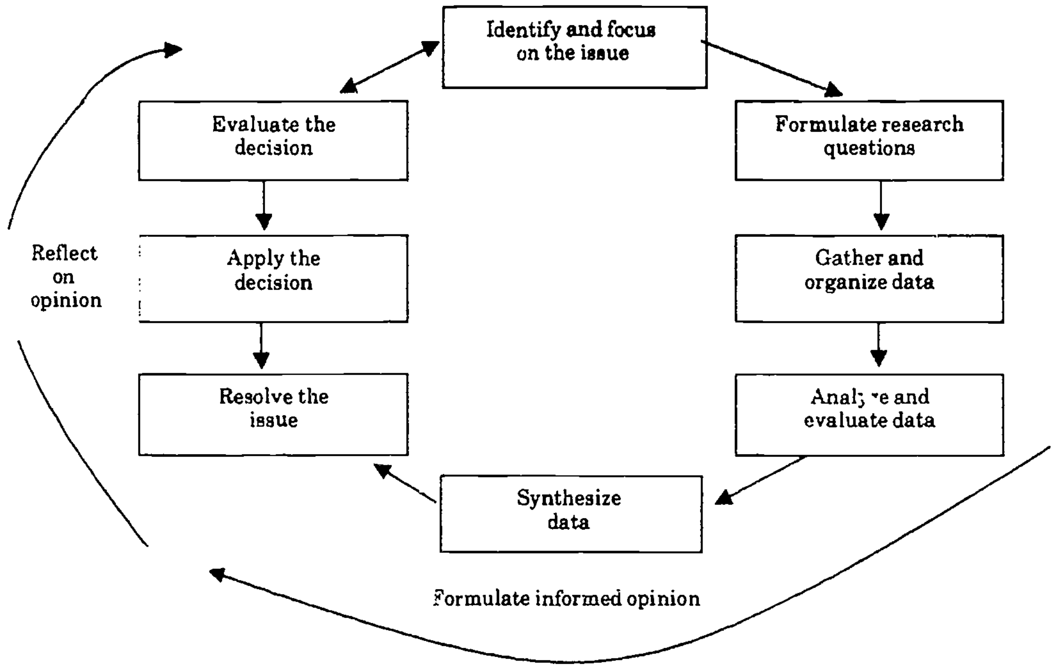
3. Students are organized into larger groups composed of individuals who hold divergent opinions (heterogeneous groups). Issue is discussed by group members.

    - Divergent viewpoints are identified.
    - The consequences of each resolution and rationale for accepting the viewpoint are discussed.
    - Personal viewpoints are questioned and possibly defended.

4. Personal reflection on the issue.



Decision-Making Model



IMPLEMENTING CONTROVERSIAL ISSUES

By including at least one controversial issue in every unit, students will expect and prepare for controversy.

Interactive debates and role-playing scenarios are two of the more effective ways of encouraging students to consider the assumptions as the basis of divergent viewpoints.

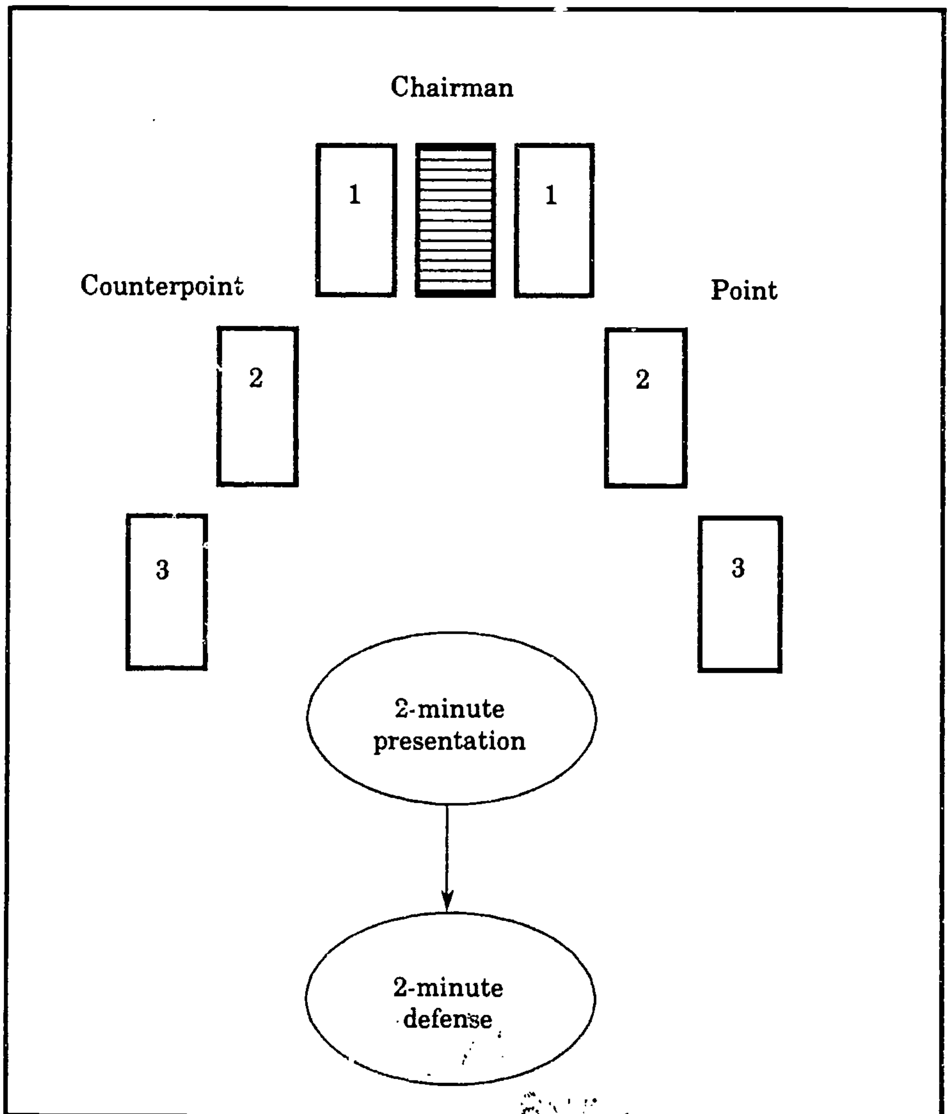
Plan to make social issues a regular part of your science program. By including at least one controversial issue in every unit, students will expect and prepare for controversy. Skills and attitudes developed during one controversy can be refined and enhanced in others. Students soon come to recognize that a deeper understanding of science-related social issues are inextricably tied with an understanding of scientific knowledge. Hopefully, the opportunity to experience science and scientific innovation from within a social context will encourage students to maintain a lifelong interest in science.

Social issues are often presented by divergent views. Interactive debates and role-playing scenarios are two of the more effective ways of encouraging students to consider the assumptions as the basis of divergent viewpoints. For example, the industrialist and environmentalist are often portrayed as adversaries. It is important to note that both may present sound and logical arguments. However, each possesses a different world view. The argument is not centred on whether or not economic growth is important for a society, or whether environmental protection is important. Few environmentalists would argue that economic strength is unimportant, nor would many industrialists propose that environmental protection is unimportant. Both groups attempt to provide a better quality of life. However, industrialists and environmentalists present divergent opinions about what constitutes a better quality of life.

Possible Structure for Implementation

Select a small group of students who agree with one response to the social issue and another group of students, preferably of equal numbers, who support divergent and opposing point of views. Students will be given an opportunity to provide arguments that support and defend their viewpoint. Each student will also be provided with an opportunity to challenge opposing viewpoints.

Suggested Room Set-up for Debate



The following recommendations may help your debate:

Suggestion	Reasons
Select an independent chairman to monitor time of presentation and response to questioning. Do not participate in questioning until the summary, if at all.	During the debate, students often look to the teacher for confirmation of their world view. A generally greater information base makes a teacher a worthy ally.
Provide some initial background information and ask probing questions before beginning the debate or role-playing scenario.	Students should understand the scientific and technological underpinnings that provide the framework for understanding the issue. The boundaries of the issue must be defined.
Do not expect to find a winner of the debate. Discourage the notion that one viewpoint is correct and the other is wrong.	The importance of the debate should not be considered as one side dominating another. Most debates don't have clear winners and losers. They do, however, provide an opportunity to consider the opposing viewpoint and critically analyze their own viewpoint.
In selecting group members for the interactive debate or role-playing scenario, consider gender balance. Hopefully, all groups will have a balance of motivated students who are willing to express themselves. The discussion should not be approached from the idea that the group that dominates the conversation wins the argument.	As much as possible, viewpoints should not be aligned with easily identified subgroups. The focus should be placed on the argument, not upon who delivers the argument. Opinions should not be viewed as female responses or male opposition to a viewpoint. Similarly, a point of view held by an honours student is not more credible than a student who finds the work difficult.
Students preparing for debates should coordinate their presentations with other group members. A list of important points should be written out for quick reference.	Redundant arguments should be avoided. Students involved in the debate must be accountable. Coordination insures that each student has an important contribution. Evidence of research should be present.
During the debate or forum, students should be directed to listen to and respect divergent points of view.	Ideally, controversial issues should promote tolerance and understanding. A greater understanding and appreciation of the reasons that certain groups hold certain values can be modelled.

Alberta EDUCATION

CONTROVERSIAL ISSUES

BACKGROUND

Controversial issues are those topics which are publicly sensitive and on which there is no consensus of values or belief. By their nature, controversial issues generate diverse opinions and debate on the distinctions between right and wrong, justice and injustice, and on interpretations of fairness and tolerance. They include topics on which reasonable people may sincerely disagree.

Opportunities to deal with sensitive issues and topics are an integral part of the education programs and schooling process in Alberta. Alberta Education recognizes that education cannot remain neutral on all issues or avoid all topics that are controversial. Alberta Education also recognizes that courses of study and education programs offered in Alberta schools must handle controversial issues in a manner that respects the rights and opinions reflected in different perspectives, but that rejects extreme or unethical positions.

For sound judgment to be made, students should have experiences in selecting, organizing and evaluating information. The educational benefits to be gained by studying controversial issues include the development of critical thinking, moral reasoning, and an awareness and understanding of contemporary society.

POLICY

Alberta Education believes that studying controversial issues is important in preparing students to participate responsibly in a democratic and pluralistic society. Such study provides opportunities to develop student's capacities to think clearly, to reason logically, to open-mindedly and respectfully examine different points of view, and to reach sound judgments.

LEGISLATION

School Act

25 (1) The Minister may do the following:

(a) prescribe courses of study or education programs, including the amount of instruction time;

(b) authorize courses of study, education programs or instructional materials for use in schools;

(c) prescribe the minimum total hours of instruction a board shall make available to a student in school year;

(d) approve any course, education program or instructional material that may be submitted to the Minister by a board or another operator of a school for use in a school;

(e) subject to the right of a board to provide religious instruction, by order prohibit the use of a course, an education program or instructional materials in schools;

(f) by order adopt or approve goals and standards applicable to the provision of education Alberta.

Other legislation:

Alberta Bill of Rights, R.S.A. 1980, Chapter A-16

Canadian Charter of Rights and Freedoms, Constitution Act, 1982

The Ministerial Order under section 25(2)(f) of the Act as cited in the Ministerial Orders and Directives section of this Policy Manual.

PROCEDURES

1 Sensitivity on the part of teachers, students and other participants in controversial issues shall be exercised to ensure that students and other are not ridiculed, embarrassed, intimidated or degraded for positions which they hold on controversial issues.

2 Information regarding controversial issues should:

(a) represent alternative points of view, subject to the condition that resources used are not restricted by any federal or provincial law;
(b) appropriately reflect the maturity, capabilities and educational needs of the students;
(c) meet the requirements of provincially prescribed and approved courses of study and education programs; and
(d) reflect the neighbourhood and community in which the school is located, as well as provincial, national and international contexts.

3 Controversial issues which have been pre-planned by the teacher and those which may arise incidentally in the course of instruction should be used by the teacher to promote critical inquiry rather than advocacy, and to teach students how to think rather than what to think.

4 The school should play a supportive role to parents in the areas of values and moral development, and shall handle parental decisions in regard to Controversial Issues with respect and sensitivity.

(Document Number: 02-01-07)

THEMATIC APPROACH

by David W. Blades

Although the following section speaks to the use of the six themes as a context for the Science 10–20–30 program the strategies suggested in regards to these themes can be applied to Biology 20–30, Chemistry 20–30 and Physics 20–30 as well

INTEGRATING SCIENCE 10–20–30 AROUND THEMES

1. What is an Integrated Approach to Science Education?

   Computers, automobiles, antibiotics, plastics, and grocery store scanners are but a few of the myriad technological developments made possible through scientific research and discovery. Much of this research is no longer clearly defined by the traditional fields of biology, chemistry and physics. Major advances in scientific research are now taking place in interdisciplinary areas such as molecular biology, geophysics, astrophysics, robotics, and biochemistry. These advances emphasize the extent the boundaries between traditional science disciplines have become less and less clear. As a better reflection of how science is understood by modern scientists, some educators suggest science education should focus on major ideas which transcend specific science disciplines. Such a focus is called an Integrated Approach to Science Education.

   An Integrated Approach to Science Education is one of three ways to organize science education. Each method of organization reflects a particular emphasis. Senior high school science in Alberta has traditionally focused on developing student understanding of the ideas and methods of the major science disciplines of biology, chemistry and physics. This Disciplines Approach emphasizes the unique features of the particular subjects of science. An Integrated Approach recognizes the science disciplines but focuses on broad themes in an attempt to emphasize the dynamic interplay of science concepts and the unity of science. A Unified Approach considers science disciplines artificial constructs and seeks to avoid them altogether. This approach emphasizes the unity of science with other subjects in the curriculum. Figure 1 illustrates this spectrum of science education approaches:

An Integrated Approach recognizes the science disciplines but focuses on broad themes in an attempt to emphasize the dynamic interplay of science concepts and the unity of science.

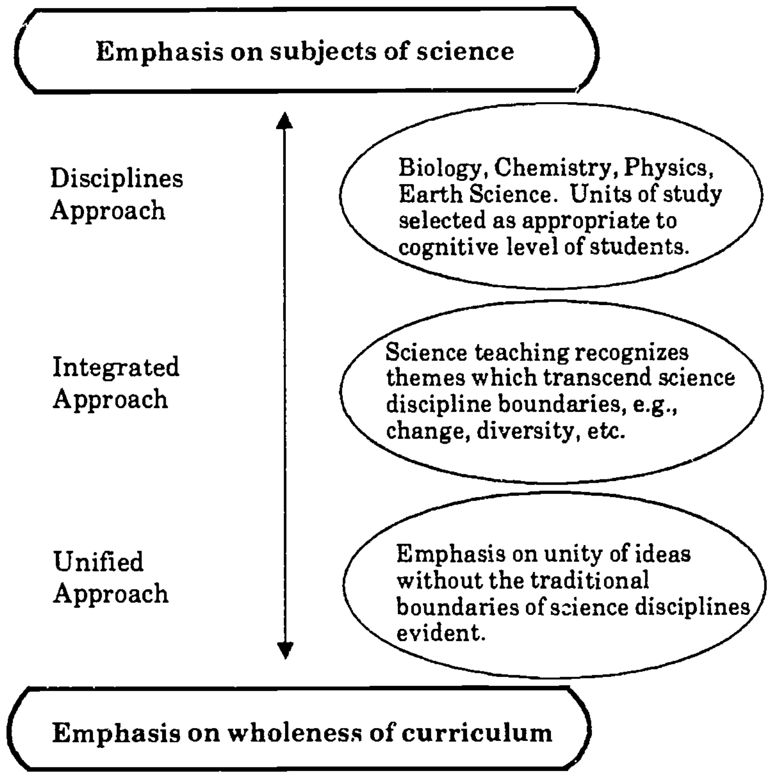


Figure 1: Spectrum of Science Education Approaches

The units in the Science 10–20–30 program still retain some aspects of the science disciplines, but the emphasis of these units is the development of students' understanding of major concepts, or themes, in science. In this way, Science 10–20–30 reflects an Integrated Approach to Science Education.

2. Why integrate science education around themes?

   Themes can be defined as "big ideas" which link the theoretical structure of the various science disciplines. Research indicates that integrating science around themes promotes student thinking skills abilities. High school students often do not make connections between their programs of study. For example, students may not see any relationship between the topics of oxidation and reduction in chemistry, and cellular respiration in biology. By emphasizing themes in science education an Integrated Approach helps students to make connections between topics. In this way, themes provide powerful conceptual organizers which encourage student thinking. Research indicates that the use of conceptual organizers contributes to gains in students' critical thinking abilities which, in turn, promotes overall student achievement.

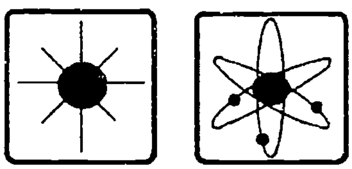
High school students often do not make connections between their programs of study.

Many educators believe an Integrated Approach helps students develop a more authentic view of science and the relationship between science, technology and society. The Science Council of Canada's summary report of science education in Canada expressed concern that the "narrow focus on science mainly for future scientists contributes to premature specialization and tends to isolate the various subject areas" (SCC, 1984, p. 14). The early specialization through a focus on a Disciplines Approach to science education in high schools tends to make science less relevant to those students who do not intend to become biologists, chemists, or physicists. A more relevant science program would recognize that the real-life problems and decisions students will face cut across science disciplines since science outside the classroom is integrated. The emphasis of themes in Science 10–20–30 encourages an integrated science education which provides an opportunity for students to develop an authentic view of modern science while revealing possibilities for students to begin to act on the problems they will face.

A more relevant science program would recognize that the real-life problems and decisions students will face cut across science disciplines since science outside the classroom is integrated.

3. What are the themes in Science 10–20–30?

There are six themes developed in Science 10–20–30. A complete description of each theme is provided in the Science 10–20–30 programs of study. These themes present a view of science as a dynamic interplay of tension and harmony centred around the study of energy and matter.



Central Themes:

Energy and Matter

In a sense, science is ultimately interested in the relationships between energy and matter. Understanding aspects of these relationships is central to the Science 10–20–30 program. Energy is defined as the capacity to do work. Energy provides living systems with the ability to maintain, grow and reproduce, and energy underlies all chemical changes. Understanding energy is basic to explaining such diverse phenomena as metabolism, weather, nuclear reactions, earthquakes, and how automobile engines work. The theme of energy is pervasive in science, linking various disciplines. In the physical science, the manifestations and transformations of energy are explored. In the biological sciences, energy flows affect organisms, and the growth and change of ecosystems. The role of energy in inhibiting and encouraging chemical reactions is central to studies in chemistry.

In a sense. science is ultimately interested in the relationships between energy and matter.

It is impossible to separate an understanding of energy from a study of matter. Just as energy undergoes change and can be found in many forms, matter exists as atoms and molecules which recombine in myriad ways. Matter can be studied at many levels, from atomic interactions to planet composition. The study of matter and the knowledge of how matter behaves is important to understanding events in the world: sound waves, temperature changes, air and water pressure, phase changes, and the movement of substances in ecosystems.

From a focus on energy and matter develop many themes that transcend science disciplines.

Related Themes: Equilibrium, Systems, Change, Diversity

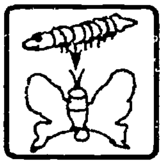
From a focus on energy and matter develop many themes that transcend science disciplines. Four of these themes are featured in the Science 10–20–30 program: Equilibrium Systems, Change, Diversity. For a full description of each of these themes, teachers should refer to the Science 10–20–30 programs of study. A brief summary of each theme is provided:

Equilibrium

Equilibrium is the state where opposing forces or processes are balanced or appear to have stopped. This balance remains until change is imposed in the system. Examples would be a healthy body, a rock at rest, or dynamic equilibrium in a chemical solution.

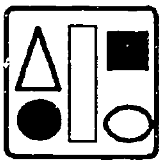
Systems

A system is any collection of objects, organisms, processes or machines which have some relationship or influence on one another. Systems generally have inputs and outputs. Some familiar systems are the solar system, an automobile engine, predator-prey relationships in an ecosystem.



Change

Change is modification or alteration over time. Change is often cyclical; for example, in the change of nutrients in ecosystems or the movement of plates in Earth's crust. Change can also be regular, as in acceleration, or irregular as in some chemical reactions or the progress of evolution.



Diversity

Diversity refers to the wide array of living and non-living matter and energy. Diversity is often approached through classification. Understanding diversity helps to discover the effects of change on systems.

As major concepts which pervade science, these themes are in dynamic tension and harmony. For example, in studying the topic of ecosystems (Science 20, Unit 2, Major Concept 5) the theme of equilibrium is reflected in population stability in ecosystems and is in harmony with understanding ecological areas through the theme of systems. These themes, however, are in tension with the theme of change which demonstrates that populations have changed over time. Yet change is in harmony with the theme of diversity which is clearly demonstrated in the many types of ecosystems present. This conflict of ideas, supported from some perspectives, contradicted from other perspectives, is part of the exciting nature of science discourse and presents to students a picture of the dynamic nature of science. The relationship between the four themes and the centrality of studying energy and matter in Science 10–20–30 is illustrated in Figure 2.

As major concepts which pervade science. these themes are in dynamic tension and harmony.

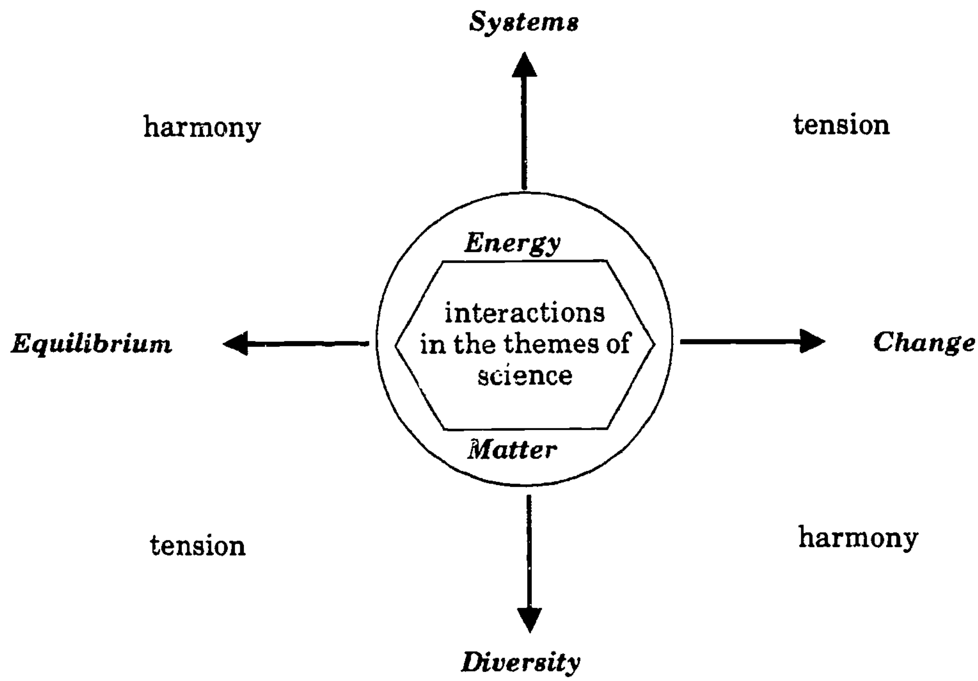


Figure 2: The Dynamic Nature of Themes in Science

5. Teaching Themes in Science 10–20–30

   The units in Science 10–20–30 reflect in topics the disciplines of biology, chemistry, physics, and Earth science. To integrate these units, themes are to be woven throughout each science course. Fig. 3 illustrates this weaving:

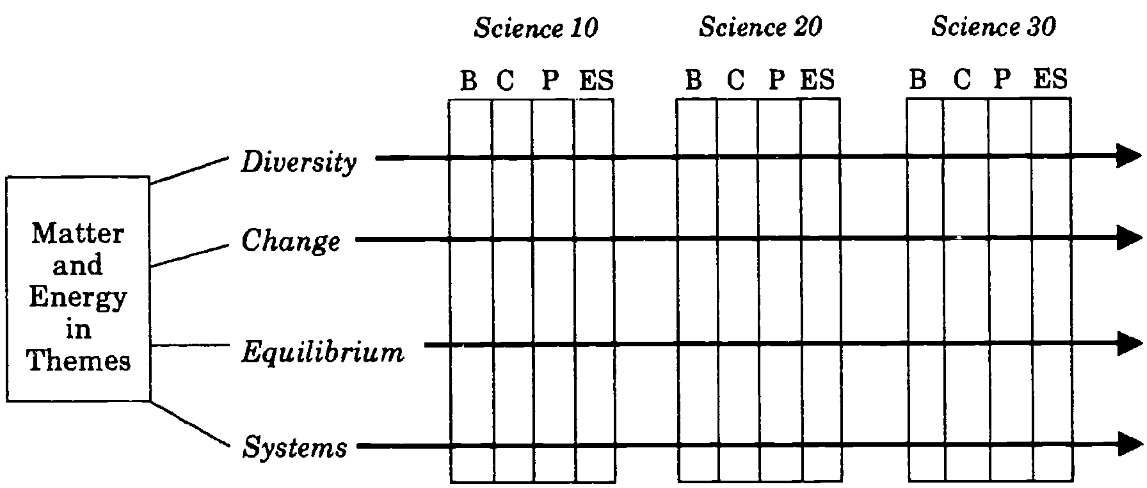


Figure 3: Weaving Themes in Science 10–20–30

B= biology, C= chemistry, P= physics, ES= Earth science

Each theme provides a focus or reference point for the units of Science 10–20–30. Emphasizing the major themes in instruction requires some planning. The following are suggested steps for teaching science from a thematic perspective:

Suggested steps for teaching science from a thematic perspective.

Step 1: Reflect on the themes

Reflect on the themes. The purpose of this first step is to develop a greater awareness and understanding of the six themes in the Science 10–20–30 programs of study. As teachers reflect on the meaning of each theme, and how the themes interrelate, the possibilities for emphasizing themes will become clearer. Many people find it helpful to write down their thoughts as they reflect. The following questions could help guide reflections on the six themes:

As teachers reflect on the meaning of each theme, and how the themes interrelate, the possibilities for emphasizing themes will become clearer.

a. What is meant by each theme?
b. In which science topics can I recognize these themes?
c. How do these themes connect between science topics?

Step 2: Unit Planning

Reflection does not stop with Step 2, but should be part of a teacher's ongoing growth in understanding how themes can be woven into a science course. Together with reflection, the next step is planning. Teachers cannot assume students will intuitively discover on their own the interconnecting themes in their science course. For Science 10–20–30 to be a truly integrated course, the major themes must be explicitly taught and highlighted. This will require planning prior to teaching Science 10, 20, or 30. Planning for the teaching of themes involves charting out the major concepts of a particular unit in a science course and then exploring on paper all the ways the topics of the unit reflect the major themes. This is essentially a brainstorming method to see connections and possibilities for teaching the major themes. Many teachers find a planning chart helpful in this process. A sample planning chart is provided on the next page of this section. The chart on the following page illustrates how a planning chart might be used.

Planning for the teaching of themes involves charting out the major concepts of a particular unit in a science course and then exploring on paper all the ways the topics of the unit reflect the major themes.

Emphasizing Themes – Planning chart for unit:

Major Themes: Energy and Matter

Subthemes → / Essential Concepts ↓	*Diversity*	*Change*	*Equilibrium*	*Systems*
Concept 1:				
Concept 2:				
Concept 3:				
Concept 4:				
Concept 5:				

Emphasizing Themes – Planning chart for unit: Science 10, Unit 3: Matter and Energy in Chemical Changes

Major Themes: Energy and Matter

Subthemes → / Essential Concepts ↓	*Diversity*	*Change*	*Equilibrium*	*Systems*
Concept 1: matter is everything that has mass and occupies space	major categories of matter: mixtures, pure substances, elements, etc. – classification of matter using the periodic table	– difference between physical and chemical properties	maintenance of elements in the body – existence of phases at melting point, boiling point	– phase changes in closed systems
Concept 2: energy is involved in each change that matter undergoes	– diversity of chemical changes: synthesis, decomposition, substitution, etc.	– energy and chemical change: exothermic and endothermic reactions	– resistance to change in reactions – driving endothermic reactions to completion via heating, removal of products	– Second Law of Thermodynamics
Concept 3: elements combine to form a vast array of compounds	– possible chemical combinations based on periodic family of selected elements	– how dangerous elements (Na, Cl) change to form useful ones: NaCl	– the flow of energy in compound formation and energy in decomposition	– chemical reactions as a closed system
Concept 4: matter has a well-defined underlying structure	– diversity of subatomic particles – relation of diversity of compound formation to ion formation	– nuclear decomposition and radioactivity – bonding and electron movement related to changes in chemical properties	– stability in atomic bonding, dynamic nature of bonding	– the atom as a system
Concept 5: matter is conserved in chemical change	– diversity of matter and energy interactions in chemical change	– stoichiometry in chemical changes	– conservation of mass in chemical changes	– industrial systems for chemical change

Step 3: Lesson Planning

Lesson planning is one of the creative acts of teaching.

There are many ways teachers can develop themes with students.

Lesson planning is one of the creative acts of teaching. Themes are useful in providing a framework students can use to connect ideas and place in context new concepts. When developing a lesson on a particular science topic, teachers should emphasize the themes that naturally fit the particular topic. The following questions can help teachers plan how to incorporate themes into daily lesson plans:

a. What themes relate to this topic?
b. How is this topic related to other topics in the theme(s)?
c. What is unique about this topic compared to other topics in the theme(s)?
d. How can the particular themes in this lesson be made explicit?

There are many ways teachers can develop themes with students. One is by direct reference to the theme itself. Teachers could build assignments around a theme, or build bulletin boards which reflect the theme. Students could keep a journal which reflects their growing understanding of the themes; teachers could have students complete written assignments on the theme. In an integrated science course, one teacher began the science class by asking questions that reviewed previous class concepts and focused on the themes being featured. There are many activities in the section on developing student thinking skills in this teacher resource manual which could be used to explore, consolidate and apply student understanding of the major themes in science.

As the teacher makes themes explicit in instruction, students will begin to see connections between topics. This recognition of patterns and concept-organizers will, with teacher encouragement, continue until students are able to fit new information into the major themes in Science 10, 20 and 30. When this happens, students take initiative in organizing ideas and expect to see how ideas fit together not only in science, but in other subjects as well. The result is a more intellectually aggressive student, willing and able to see connections between science ideas. This provides a better basis for science teachers to help students realize the interrelationships between science, technology, and society than a more strict focus on the science disciplines.

Some teachers may wish to take the integration of science one step further and try a Unified Approach to Science 10-20-30. With this approach, the units as they exist in the Science 10-20-30 program of study, or as they are presented in the textbook, are not used; instead, the science knowledge, skills and attitudes in the programs of study are reorganized around major topics which often have little resemblance to the original units.

The science knowledge, skills and attitudes in the programs of study are reorganized around major topics which often have little resemblance to the original units.

A Unified Approach to science education is not new, but has increased in popularity in the past thirty years. Educators who support unified science education feel science is best understood as a unified human activity which varies in focus (disciplines) but not in methodology. Values such as questioning, respect for logic, demand for verification, and consideration of premise and consequence characterize and typify the unity of a scientific mode of thinking. Since there exists a fundamental unity of thought in the enterprise of science, proponents of a Unified Approach feel the unity of science should be reflected in science education methodology.

A particular focus on a Unified Approach is the interrelationships among science, technology, and society (STS). Technological advances and problems—e.g., water pollution, space flight, genetic engineering—illustrate the interrelatedness and dependency of science fields of study. In this perspective, disciplines are artificial constructs with only limited use and relevancy in understanding the dynamics between science, technology and society. A Unified Approach is often portrayed as the best way to encourage student understanding of STS issues.

Some of the greatest value of a Unified Approach to science education lies in its practical expressions. Since the Science 10-20-30 textbooks and programs of study are organized from a disciplines perspective, development of a unified science course is up to the expertise of the classroom teacher. Usually, the courses that develop reflect the unique characteristics of the local school environment, building upon student interest, available facilities, and staff qualifications. What results is a course of study tailored to the unique situation of the region or school. Typically, these courses are characterized by students as being relevant, fun, and exciting. This often encourages innovative teaching practices which result in further curriculum development in the local school setting.

Development of a unified science course is up to the expertise of the classroom teacher.

This, of course, can also be very demanding on teacher time and expertise; nevertheless, research indicates that, in general, teachers who developed unified science courses felt the experience was positive. In this setting of educational innovation and local relevance, it is little wonder that research indicates student enrollment in science increases when a Unified Approach to science education is adopted in a school.

How to Unify Science Around Major Topics

Step 1: Selecting Major Unifying Topics

Teachers are encouraged to develop their own unified courses to reflect the unique needs of their educational settings.

Building a unified course begins by listing the science knowledge, skills and attitudes of a particular science course in the Science 10, 20 or 30 program of study. From this content the teacher, often in collaboration with other teachers and possibly students, chooses major topics which integrate the content of the science course. These ideas form the central topic for the course; all the content will be related to the major topic. There are unlimited unifying topics which could be chosen; teachers are encouraged to develop their own unified courses to reflect the unique needs of their educational settings. The following lists some of the characteristics of topics that teachers should consider:

For each science course, two major topics seem to be ideal.

a. The unifying topic should be simple and concrete.
b. The unifying topic should fit naturally with the science knowledge, skills and attitudes to be covered.
c. The connection between the content to be covered and the unifying topic should be straightforward and obvious to the student.
d. The unifying topic should have relevance to student needs and interests.

For each science course, two major topics seem to be ideal.

Step 2: Organizing Content Around Unifying Topics

Once the two unifying topics are selected, the knowledge, skills and attitudes of the science course are then organized and related to the unifying ideas.

This step is crucial to the success of a unified science course. Once the two unifying topics are selected, the knowledge, skills and attitudes of the science course are then organized and related to the unifying ideas. It is essential that no content from the programs of study is omitted in this step. What results is a diagram which lists topics of study and their relation to a unifying theme. The following are examples of one possible way Science 10, 20 and 30 could be unified around major topics.

Sample Unifying Topics for Science 10

Lakes and Ecosystems
- energy from the Sun and weather
- lakes in prairie ecology
- consequences of lake pollution

Learning From a Lake

Life in a Lake
- cells as the basis of life
- how living things depend on the lake
- flow of nutrients and wastes in lake

Lakes and Recreation
- properties of water, energy of water
- energy and phase changes
- seasons and lake use

Source and Extraction of Petroleum Fuels
- energy from the Sun sustains life on Earth
- some solar energy can be stored as non-renewable fuels
- how petroleum is discovered and extracted from Earth

The Petroleum Challenge

The Wise Use of Petroleum Fuels
- rates of consumption
- innovations in petroleum use
- life without petroleum

Petroleum Fuels and Products
- matter has mass and space
- energy and changes to matter
- elements combine to form compounds
- conservation of energy in the use of petroleum fuels

Sample Unifying Topics for Science 20

Life of a Carnivore: Alberto-saurus

Uncovering a Dinosaur
- changes on Earth
- paleontology in Alberta
- the fossil record and Albertosaurus
- Alberta in the past

Learning From the Past
- present major ecosystems
- how living things adapt to changes in ecosystems
- present changes in global ecology and lessons from the past

Life and Death in the Late Cretaceous
- movement of energy in a biosphere
- ecosystem of the late Cretaceous
- change in ecosystems: what killed the dinosaurs?

The Automobile

How an Automobile Engine Works
- hydrocarbons as fuel
- chemical reactions in the internal combustion engine
- balancing chemical reactions
- oxidation and reduction and pollution control

Convenience to Crisis?
- the greenhouse effect and the gasoline engine
- safe operation of the automobile
- finding alternatives to the automobile

Motion of an Automobile
- conversion of chemical energy into mechanical energy
- basic automobile maintenance
- describing the motion of objects
- Newton's Laws, fuel efficiency and automobile design
- momentum and driving safety

Sample Unifying Topics for Science 30

Life Aboard a Space Station

Maintaining an Artificial Environment
- chemistry of an environment
- monitoring environment quality
- waste management
- energy demands in a space station, solar power

Communicating With a Space Station
- the field theory
- electromagnetic spectrum
- the study of the universe from a space station
- global energy needs and the role of a space station

Living in an Artificial Environment
- major body systems
- the adaptation of the body systems to weightlessness
- preventing disease in a confined environment
- monitoring health: acid/base chemistry of the blood

Population Growth and Control

Human Population Dynamics
- the control of disease
- prevention of birth
- extension of life span and quality of life
- present population growth rate and consequences

Energy Requirements of a Growing Population
- the Sun as the major source of energy on Earth
- renewable and non-renewable energy sources
- balance between energy consumption and quality of life
- possible alternate energy sources: risks and benefits

Population Growth and the Environment
- monitoring pollution
- environmental effects of acids and bases and organic compounds
- satellite technology to monitor effects of pollution growth and the environment

These ideas have been provided as samples to illustrate how the science courses can be unified. Most teachers will develop their own, unique unifying ideas based on the needs and interests of their students and availability of resources.

Step 3: Building Expanded Unified Courses

The final step to designing a unified science course involves expanding the topics into a coherent course.

The final step to designing a unified science course involves expanding the topics into a coherent course. What develops in this step is a course outline that lists the central, unifying idea and the related subtopics, with a subsequent breakdown of the content referenced to the Science 10–20–30 programs of study document. Teachers have found cooperative planning helpful at this stage in the development of a unified course. Some of the methods of brainstorming and elaboration found in the sections on thinking skill development in this teacher resource manual could be helpful in expanding on the topics of a unifying idea.

Developing a unified science course is very demanding. It requires teacher ingenuity and detailed planning, and a group of students who are not dependent on the sequential use of a textbook. However, teachers find the challenge of unifying science courses quite satisfying. In schools where unified science courses have been developed there is evidence to indicate:

a. an increased elective enrollment in science
b. a greater proportion of students going to post-secondary study choose science as a major than a strict disciplines approach to science.
c. students' grades are at least as good as their peers who choose discipline-oriented science courses.
d. students develop high levels of scientific literacy when exposed to unified science.

These results provide an invitation for science teachers to explore the possibilities of developing unified science courses in their schools.

ENVIRONMENTAL CONNECTIONS

by Dr. Rick Mrazek

ALBERTA EDUCATION POLICY

One of the goals of school programs is to help students think critically and make responsible decisions based on a careful analysis of a situation. Students are encouraged to *develop a commitment to the careful use of natural resources and to the preservation and improvement of the physical environment* (Goals of Education, adopted by the Legislature in 1978).

Environmental Education is viewed as an interdisciplinary activity, consistent with the goals of basic education and using the resources of many government, social and private agencies, groups and individuals.

Alberta Education recognizes a shared responsibility for ensuring that appropriate activities leading to this goal are undertaken. Thus, Environmental Education is viewed as an interdisciplinary activity, consistent with the goals of basic education and using the resources of many government, social and private agencies, groups and individuals.

Alberta has prepared a catalogue of essential concepts, skills and attitudes that students must develop to function in, and to contribute to society. The catalogue addresses learning outcomes in ten areas, including global and environmental awareness. As existing courses are revised and new courses developed, the content is being reviewed to ensure that the essential learning outcomes for students are incorporated.

In the case of the senior high science curriculum, the STS emphasis places environmental issues that are influenced by science and technology in the context of choosing actions that are most appropriate for the circumstances. Students explore how scientific and technological knowledge can help us make informed decisions about issues, and become aware of how societal pressures influence these decisions.

INTEGRATION OF ENVIRONMENTAL CONCEPTS IN SCIENCE COURSES

Consistent with Alberta Education policy, most of us would support the idea that education must work to help each student develop an awareness of and a sensitivity to the environment and its problems, acquire knowledge and understanding about the environment, foster positive attitudes, values and patterns of conduct toward the environment, and develop the skills needed to effectively

Science education in a science-technology-society context focusing on the environment must help students develop a sense of responsibility and commitment to the future, preparing them to carry out the role of defending and improving the environment on behalf of present and future generations of all living things.

discharge the responsibilities of citizenship in improving and protecting the environment at all levels – local, national, global and universal. In doing so, Environmental Education must consider all aspects of the environment – natural, built, technological, social economic, political, cultural, moral and aesthetic – and acknowledge their interdependence, emphasizing an enduring continuity linking actions of today to consequences for tomorrow, and the need to think in universal terms.

To accomplish this in science programs, science education must be continuous, must pervade all grade levels, and offer students experiences as concrete and direct as possible, involving them in investigating real society-technology-envii ımental issues and problems in their own community from a position of neutrality, *with no position being advanced in favour of another.*

In short, science education in a science-technology-society context focusing on the environment must help students develop a sense of responsibility and commitment to the future, preparing them to carry out the role of defending and improving the environment on behalf of present and future generations of all living things.

Throughout the senior high school program, concepts, skills and attitudes associated with Environmental Education are readily identifiable and can be summarized in terms of the following general goals.

Ecological Foundations . . . The Knowledge of Key Concepts and Allied Ecological Principles

1. Students gain sufficient knowledge of ecology to permit them to make ecologically sound decisions with respect to both humans and the environment.

   The Awareness of Issues and Human Values . . . The Knowledge of How Human Activities May Influence the Relationship Between Quality of Life and Quality of the Environment

2. Students gain an understanding of the ways in which human cultural activities (economics, religion, politics, social customs, etc.) influence the environment.

3. Students gain an understanding of the ways in which individual human behaviour affects the environment.

4. Students gain an understanding of a wide variety of environmental issues and both the ecological and cultural implications of these issues.

5. Students gain an understanding of the various alternative solutions for solving (or partially solving) particular environmental issues. The ecological and cultural implications of these solutions are considered.

6. Students gain an understanding of the roles played by differing human values in environmental issues.

The Investigation and Evaluation of Issues and Solutions . . . The Development of Skills Necessary for the Actual Investigation and Evaluation of Environmental Issues and of the Alternative Solutions to those Issues

7. Students develop skills that will enable them to identify and investigate environmental issues using both primary and secondary sources of information.

8. Students develop skills that will enable them to analyze environmental issues and the associated value perspectives with respect to their ecological and cultural implications.

9. Students develop skills that will enable them to identify alternative solutions for particular issues and to evaluate those solutions with regard to their cultural and ecological implications.

10. Students develop skills that will enable them to identify and evaluate their own value positions related to particular issues and the solutions proposed for those issues.

11. Students are provided with opportunities to participate in the valuing process in order to examine their own values with respect to both quality of life and quality of the environment.

Citizenship Action . . . The Development of those Skills Necessary for Students to take Appropriate Environmental Action

12. Students develop citizenship skills that will enable them to take individual or group action (e.g., persuasion, consumerism, political action, legal action, eco-management) where such action is appropriate for the purpose of solving, or helping to solve, particular environmental issues.

13. Students are provided with opportunities to take citizenship action on one or more environmental issues.

MAPPING OF OPPORTUNITIES FOR INTEGRATION

In the new senior high science program, there are at least 493 specific opportunities identified in the areas of attitudes, concepts, knowledge, skills and STS connections, with 259 of these in Science 10–20–30, 107 in Biology 20–30, 76 in Chemistry 20–30 and 52 in Physics 20–30. Students and teachers are provided with significant direction for inclusion of environmental education in the science program.

In the new senior high science program, there are at least 493 specific opportunities identified in the areas of attitudes, concepts, knowledge, skills and STS connections.

These opportunities tend to follow three major themes of energy, environmental impact of technology and safe handling of hazardous/dangerous materials. The following examples, *in combination with materials and directions provided in the senior high science inservice packages*, will help illustrate how Environmental Education can be effectively integrated into the senior high science program.

Example 1

In the Science 10 Program of Studies, Unit 1, Concept 1, the major theme is energy. In this unit, there are at least 34 opportunities to teach Environmental Education, nine of them relating to Concept 1. Therefore for this one lesson, it is possible to integrate environmental education into this section by involving students in their own research.

Since the trend in science education is to try to reduce lecture time, the students are challenged to do more independent research. This also allows the teacher to have more individual contact with the students. On page 32 of *Focus on Research* (Alberta Education, 1990), there is an excerpt from the junior high school TRM that outlines how to teach students to gather information.

If the teacher is going to encourage a bias-balanced approach, then critical thinking and problem solving should also be taught to the students. *Teaching Thinking* (Alberta Education, 1990) provides teachers with a good framework to help students hone their critical-thinking skills.

After the students complete the research, they can express what they have learned through art. Unlikely as it may seem, the hydrological cycle can be graphically represented in many different and interesting ways, depending on the creativity of the students. They can label the drawing appropriately and integrate information into the drawing, such as the length of time required for water to go from a large body of water into the atmosphere and return. The teacher has a method of evaluating what has been learned and the students have fun at the same time.

STS concepts can be easily integrated into this lesson. This lesson fits into the first six goals of Environmental Education identified earlier, as well as goals 12 and 13. The students will gain an understanding of how water cycles by reading the materials chosen, and the knowledge is then internalized when they draw the cycle. This will cover the first six goal statements of Environmental Education. Should the discussion go further, the students will be able to make decisions that affect their own lives and others around them.

This integrated approach would cover the cognitive, psychomotor and affective domains. Using similar approaches in other units, the same effect can be achieved.

Example 2

Another major theme in the high school science program is the environmental impact of technology. In Unit 3 of Chemistry 30, the topics are equilibrium, acid and base chemistry. In this unit there are two STS connections where the teacher has the opportunity to integrate Environmental Education into a lesson. The acid and base chemistry concept has many environmental implications. The obvious one is the problem of acid precipitation.

Most students enjoy the laboratory atmosphere since they are engaged in "hands-on" activities. By using pH meters (if available), they can build on the concept of proton transfer learned in the classroom. These instruments give more accurate indications of acidity than litmus paper or indicator solutions and show real-time changes in acidity, which is more exciting for students.

Additional activities could include a study of the effects of varying concentrations of acid on different materials (e.g., concrete, various metals, fabrics, wood/paper products). The students could use different concentrations of vinegar to perform taste tests for palatability relating to plant/animal tolerance of acid content in their respective food sources in their personal environment.

Thinking skills can be employed in these additional activities by having the students predict the effect of the acid on the various materials and the global implications of the potential effects of the acid. A good model to use is the science process skills model outlined on page 71 in *Teaching Thinking.* By using this model, the students may be able to design their own experiments rather than performing "cookbook" experiments in which they normally assume that there is a "correct" outcome.

The concepts covered in this unit encompass a number of the Environmental Education goal statements, including statements 2, 6, 7, 9, 10 and 11. Besides learning the concept of proton transfer in acids and bases, they also gain an appreciation of the larger, global problem of acid precipitation as it appears in terms of its chemical nature or possibly the socio/political/economic implications of acid precipitation.

This example, like the previous one, encompasses the cognitive (content of lesson), the psychomotor (lab manipulation skills) and the affective (attitudes toward the creation of acid precipitation) domains. Since this science program emphasizes the affective domain, the students should be encouraged to engage in discussion while performing the various lab tests/experiments.

Example 3

Physics may seem to provide few links to environmental issues. With most topics in physics, there are no direct links to the environment, but there are many related concepts to Environmental Education. Unit 3 of Physics 30 deals with magnetic forces and fields, which have importance in power generation. Therefore, Environmental Education will fall in the STS connections rather than under concepts or knowledge. There are two opportunities to explore Environmental Education in this unit.

A combination of laboratory work and the use of writing can be a useful approach to teaching this unit. The students can experiment with the effects of magnetic fields, which gives them the foundations in the knowledge to be learned. They can experiment with the effects of magnetism on plants and the effects of magnetism with other magnetic materials.

As an extension, the students can do extra research on the reasons why superconductivity is important in terms of society. Again, the teacher can refer to page 32 of *Focus on Research* for a guideline students can use. Examples are maglev transports and nuclear fusion containment. The STS connection includes the reduction of fossil fuel consumption using mass transit and power generation via nuclear fusion (i.e., no long-lasting radioactive waste and no danger of meltdown).

Exposing individuals to various learning styles will serve to develop use of more holistic, meaningful approaches to dealing with science–technology–society environmental issues and problems.

This concept lends itself to attaining environmental goal statements 2, 5, 7, 8, 9 and 10. Since the use of fossil fuels is a pressing issue, the need for alternate methods of power generation is important. Therefore the link with magnetism (in particular superconductivity) becomes very important.

Note: When considering methodologies for integrating goals and objectives of Environmental Education in the science program, it is important that individual learning preferences be considered. Subscribing to such an approach will foster a more personal relationship to the goals and associated objectives. Exposing individuals to various learning styles will serve to develop use of more holistic, meaningful approaches to dealing with science–technology–society environmental issues and problems.

AGRICULTURE CONNECTIONS

by Daryl Chichak

Agriculture has global, national and local importance. Besides the obvious—we all eat—agriculture also has a major impact on our Albertan lifestyles. One in three jobs in Alberta is influenced by agriculture, either directly or indirectly. As well, a major portion of Alberta's economy is driven by the agriculture industry, which is mainly an export business.

One in three jobs in Alberta is influenced by agriculture, either directly or indirectly.

Agriculture is thus a logical choice as a specific learning context for students of the senior high science program. Several examples of how an agriculture context can be used to facilitate learning in the various senior high science programs follow.

ELEMENTS OF LIVING SYSTEMS

In Science 10, Unit 3, Major Concept 1, the students are expected to be able to identify the elements that are most prevalent in living systems. A discussion of the elements, selenium, Se, and sulphur, S, can be introduced here. Sulphur and selenium belong to the same chemical family and affect the metabolism of plants and animals, therefore affecting agriculture.

As an example, consider a farm in the western part of the province where the soils are generally acidic and have a limited amount of required nutrients, including selenium. Assume that the ideal crop production in this region, given the nutrient balance, is one tonne/hectare. With the addition of fertilizers to the land, you may receive a yield of two to three tonnes/hectare. The fertilizer used increases the amount of sulphur in the soil, but leaves the amount of selenium unchanged.

When you increase the amount of sulphur in the soil, the plant's transport system will take up more sulphur than selenium. If the selenium concentration falls below 100 parts per billion in a crop fed to animals, the consequences can be disastrous.

Selenium deficiencies can lead to white-muscle disease in calves and heart lesions in pigs. Challenge your students to explain why a cattle producer in southern Alberta would have reported cases of white-muscle disease when his/her land is not selenium-deficient. Through scientific research and investigation it was discovered that this producer purchased hay grown on selenium-deficient soil in northwestern Alberta. Calves suffering from white-muscle disease can be treated with selenium injections. Salt blocks with added selenium are also available for cattle and are useful in low selenium soil areas. However, farmers must be careful as an excess of selenium is also problematic. Selenium can cause alkali disease in animals that feed on vegetation grown in soils that contain an excess of selenium. Selenium poisoning can result in loss of appetite, loss of tail hair and sloughing of the hoof. Eventually the animal dies from respiratory failure, starvation and thirst.

OXIDATION-REDUCTION REACTIONS

In Chemistry 30, Unit 2, Major Concept 1, you can analyze oxidation-reduction reactions that occur in agricultural contexts. One example of this relates to the element, selenium, introduced in the previous section. Selenium is required by animals to make glutathione peroxidase, an enzyme that prevents membrane damage from free radicals and other oxidizing agents. Two other oxidation-reduction reactions of ultimate importance to life and thus to agriculture are respiration and photosynthesis.

DISPOSAL OF ANIMAL BY-PRODUCTS

When discussing disposal problems related to used materials in Science 10, Unit 3, Major Concept 3, you can provide information showing that all parts of beef cattle are used commercially, including the non-meat parts. Not only do beef cattle provide meat, they assist in the medicine industry and provide both edible and inedible by-products.

Tallow (derived from beef fat)	Crayons, explosives, inks, chalk, car tires, candles, matches, fabric softeners, variety of soaps
Glycerine (derived from beef tallow) $C_3H_8O_3(CH_2OHCHOHCH_2OH)$	Lipstick, toothpaste, hand and face creams, cough medicine
Oleo stock (derived from beef fat)	Margarine, shortening, oleo stearin
Oleo stearin	Candy, chewing gum
Hooves, horns and bones	Fertilizers, bone china, glue, buttons, animal feeds, piano keys
Edible gelatin from horns and bones	Gelatin products, ice cream, marshmallow, canned meats
Non-edible gelatin	Photographic film, toothbrushes, sandpaper, violin strings, wallpaper
Intestines	Natural sausage casings
Hide of cattle	Leather products
Fine ear hairs	Artists' brushes

From *Just Facts: The Alberta Beef Industry and The Environment.* Used with permission of the Alberta Cattle Commission.

REGULATING PHYSIOLOGICAL PROCESSES

In Biology 30, Unit 1, Major Concept 1, when studying the range of endocrine glands, the hormones they produce and the effects of those hormones, you can present cattle as walking medical storehouses.

Pancreases from both cattle and pigs are used to isolate insulin. To supply a diabetic with enough insulin for a year, 26 animal pancreases are required. Not all insulin for the treatment of diabetes comes from animal pancreases. Today over half the insulin in Canada is produced through a process of genetic engineering. (In 1992, 45% came from mixed animal sources and 55% was human genetically engineered synthetic insulin.)

The chart that follows provides several other examples.

MEDICAL PRODUCTS FROM CATTLE	
Medical Product	**Use**
Pancreas	Insulin for diabetic treatment
ACTH (adrenocorticotropin) – extracted from the pituitary glands	Treats leukemia, anemia, allergies, respiratory diseases
TSH (thyrotropin) – extracted from the thyroid	Stimulates the thyroid gland
Heparin – extracted from the lungs	Treats burns, frostbite
Thrombin – extracted from the blood	Promotes blood coagulation
Epinephrine – extracted from the adrenal glands	Relieves symptoms of hay fever, asthma, allergies
Parathyroid hormone extracted from the parathyroid glands	Treats thyroid deficiency
Rennet – mild enzyme from the stomach	Helps infants digest milk

From *Just Facts: The Alberta Beef Industry and The Environment*. Used with permission of the Alberta Cattle Commission.

Further to this topic, the teacher can present the controversial issue, "Should cattle be used as medical storehouses?" Students can then research and play various roles such as radical animal activist, medical researcher, person with diabetes, pharmaceutical company representative, company shareholder, and member of the public at large. Have the role players present their cases to a government commission considering legislation to prevent cattle being used as pharmaceutical storehouses.

FOOD PRODUCTION AND PROCESSING

In Biology 20, Unit 4, Major Concept 1, the role of food additives in the agricultural industry can be explored. There has been much debate round the subject of beef for commercial sale in Alberta possibly containing dangerous amounts of antibiotics and hormones that could be harmful, particularly to children. (Antibiotics are given to cattle to prevent or fight diseases.) To protect the public in Alberta, beef with any traces of antibiotics or amounts of hormones which exceed federally defined levels, cannot be sold. Oestradiol, a form of estrogen, is an anabolic steroid that increases the animal's efficiency in converting energy or feed into muscle, instead of fat. The cattle metabolizes or breaks down the oestradiol in its body.

In some cases, estrogen may be given to breeding-stock so that the cows all cycle at the same time. This way, the cattle breeder can have calving season at a convenient time and not year-round when conditions may not be favou ble.

ESTROGEN COMPARISON	
Source	**Estrogen in Nanograms***
100 g beef from untreated steer	1.2
100 g beef from treated steer	1.9
100 g peas	400
100 g cabbage	2,400
Boy's daily production	41,000
Female (non-pregnant) production	480,000 average (varies with menstrual cycle)

Comparisons
Estrogen levels: 1 pint of beer = 100 g of beef

Daily dose of oral contraceptives: 2,500 times greater than a serving of beef from a treated animal.

*Nanogram: one-billionth of a gram

From *Just Facts* – used with permission of the Alberta Cattle Commission

In the same unit, when investigating the role of irradiation in preventing food spoilage, you can examine the process of hydrocooling, which is used on corn crops harvested in the Taber, Alberta area. When the corn is harvested, it is immediately shipped to the processing plant. At the plant, the corn is run through a machine that pours ice-cold water over the corn cobs. This hydrocooling process helps keep the cobs fresh and prevents spoilage. Hydrocooling slows the plant's metabolism. It stops the conversion of the sugar in the corn to starch. Sugar is sweet, while starch is flavourless. Freshly picked fruit and vegetables taste sweeter than fruit and vegetables that have been sitting in the sun or a storage bin for long periods. Allowing them to sit after harvest without cooling, continues the sugar-to-starch conversion, reducing sweetness.

THE BIOSPHERE

When explaining the hydrologic cycle and the water balance of agricultural systems in both Unit 1 of Biology 20, and Unit 1 of Science 20, it is important to examine all sides of an

Students must have the opportunity to explore various perspectives on science-related issues and develop an informed opinion, open to modification in the light of new information.

issue such as irrigation systems and the construction of dams like the Oldman River Dam. If the media represent only the views of the environmentalists and activists, a biased one-sided view of the benefits and risks related to irrigation farming results. Students must have the opportunity to explore various perspectives on science-related issues and develop an informed opinion, open to modification in the light of new information. It is conceivable that southern Alberta would be a desert if it were not for irrigation and the dams being built. Irrigation has allowed the conversion of arid land into productive land, and has had an enormous effect on Alberta's export economy. There are over 100 different varieties of crops grown in southern Alberta that are used strictly as an export commodity, many of which would disappear without irrigation. Irrigation has given southern Alberta and the province an economic gain. This agricultural perspective is an important one to ensure students explore.

In Unit 1 of Science 20 and Unit 3 of Biology 20, when studying the biosphere and ecosystems, students can investigate the possible effects of irrigation systems on the different ecosystems of our environment.

You can create an excellent controversial-issue role-play activity for your classroom based on the issue of whether or not dams should be built in southern Alberta.

To demonstrate how ecosystems change over time, the ideal would be a field investigation of pasture land that has been unattended for various lengths of time. An alternative would be a picture study with display and analysis of various pictures of land in which grasses, small shrubs and, ultimately, trees have taken over. Succession takes a substantial amount of time to occur on pasture land so showing pictures of different plots of land demonstrating the stages of plant succession from pasture to forest is an efficient teaching method when an actual field study is not possible.

THINKING GREEN

In chemistry 30, Unit 4, Major Concept 1: in Science 30, Unit 2, Major Concept 4: and in Chemistry 20, Unit 4, Major Concept 1, explore how the sugar beet industry can have a dramatic effect on our lives. Research has shown that sugar beet by-products, which include beet pulp and molasses, can be used in industry, animal feed, pharmaceutical and alcohol production. Specific uses may one day include production of biodegradable plastics, surfactant for use in soaps, and anti-slick, non-rusting treatments for roadways. All these uses can provide excellent research topics for students.

ALTERNATIVE ENERGY SOURCES

The objective of Chemistry 30, Unit 1, and of Science 30, Unit 4, Major Concept 1, can be demonstrated in Activity 9 of *The Business of Agriculture, Fuelling the World of Wheels*, a resource available from the Agriculture in the Classroom Program. In this activity, students investigate the technology of producing ethanol fuel as an alternate energy source. Students are encouraged to appreciate the creativity in devising alternative methods of using biomass energy and to value the potential of using biomass as an alternative energy source.

When covering harnessing the wind, another alternative energy source, consider the example of a partially wind-powered turkey farm outside Taber, Alberta. The farm's huge wind turbine, powered by strong winds from the Crowsnest Pass, produces enough electrical power to partially run the operation and, at peak periods, supply excess electricity to the provincial power grid.

KINEMATICS AND DYNAMICS

When explaining the concepts of kinematics and dynamics in Physics 20, Unit 1, choose some agricultural contexts for problems you generate. For example, what is the potential energy of an 80 kg bale of hay when it is pulled to the top of a hay stack 10 m above the ground? What is the speed of the bale just before it hits the ground? What is the momentum of the bale? Have the students calculate the power and work done by farm machinery.

Have the students calculate the power and work done by farm machinery.

In Unit 2 of Physics 20, the students can observe the application of principles of uniform circular motion in various types of farm equipment. On combines used to harvest peas, there is a circular drum that separates the pods from the plants. A drum is also used in combines to separate the seeds from the husk.

When we solve satellite motion problems, using circular motion approximation, explain to the students how agriculture makes use of satellites. Satellites provide immediate and accurate information about the status of crops and soils. Through satellite pictures, agriculturists can predict which areas of the province will suffer from drought conditions and which areas will be productive.

Students can be challenged to evaluate the effects of living on a space station. What agricultural difficulties would they encounter? How will plants react to weightlessness? What do they think would happen to the tomato seeds brought back from a shuttle mission?

LIGHT AND ENERGY

In Physics 20, Unit 4, Major Concept 2, students must demonstrate an understanding of the effect of light on living organisms. Ask students what effect light has on the growth of certain crops. For example, compare the effect of light on growing mushrooms with growing beans or tomatoes.

Ask students what effect light has on the growth of certain crops.

In Physics 30, Unit 1, Objective 2, when investigating and reporting on technology developed to improve the efficiency of energy transfer, examine the efficiency of farm equipment. During the 1800s and early 1900s farmers used horses to pull their ploughs and wagons. With technological development, the horse has been replaced with mechanically efficient modern machinery. What advances have been made in tractors, combines and irrigation systems to make them more energy efficient?

What advances have been made in tractors, combines and irrigation systems to make them more energy efficient?

Many advances in irrigation farming have been made. Historical records show that the Egyptians used irrigation in the year 2000 B.C. They used surface gravity irrigation. The Egyptians sloped their fields and funnelled water into furrows dug in the fields. Today, some farmers still use this "flood irrigation". Their fields are sloped so water, brought from a dike using canvas dams and plastic siphon tubes, flows downhill.

With time, a "lateral-wheel-move" (side-roll-wheel line) irrigation unit was developed. Water was pumped from a dike to the side-roll-wheel system, which can extend approximately 400 m. The system is made of galvanized pipe sections, each of which contains sprinkler heads. Every six hours the farmer must move the irrigation system left or right across the field.

Eventually a "pivot irrigation system" was developed. This system moves automatically in a circle around the field controlled by a computer system or control panel on the pivot. The farmer can program how much water he wants placed on the field and how many times in a certain period he wants the pivot to move. This irrigation system is less time-consuming, but more capital-intensive, than other types of irrigation systems.

In Science 20, Unit 1, Major Concept 5, and Biology 20, Unit 3, when investigating how populations are adapted to their environment, the ramifications of wild game farming (e.g., elk farming) can be studied.

The genetic section of Biology 30, Unit 3, is an excellent place to integrate agriculture. At Agriculture Canada's Lethbridge Research Station researchers are performing genetic crosses to develop new types of seeds and grains that can withstand various diseases, soil conditions and growing seasons, thereby enhancing the province's agriculture industry. When new strains of grain are developed, samples are sent to seed banks for safekeeping.

Genetic research encompasses more than just crops. Genetic research on cattle has resulted in cattle being bred for specific traits, such as exceptional milk or beef production.

Native species of seeds are also sent to the various national seed banks to avoid loss of any species of seed. A national seed bank is a resource which can provide a vast genetic pool. Such a gene pool helps retain the genetic diversity of plants necessary for disease resistance and environmental rigor. For example, in the early 1970s in the United States, the major corn hybrid used for crops was susceptible to blight. Without access to a seed bank, the discovery of a gene that resisted corn blight would have been impossible; conceivably, we would not have corn today. The gene pool was also required to find a gene that would be resistant to rust in wheat, sawfly in wheat and black leg in canola. Plant Gene Resources of Canada is such a seed bank which specializes in oats and barley. An International Plant Genetic Resources Institute is to be set up in the summer of 1992.

Genetic research encompasses more than just crops. Genetic research on cattle has resulted in cattle being bred for specific traits, such as exceptional milk or beef production. Breeding takes place through natural as well as artificial means.

Western Breeders at Balzac, Independent Breeders at Balzac, and Universal Breeders at Carstairs, are three Alberta companies that export bull semen and cattle embryos for use in artificial breeding programs. The advantages of using artificial insemination (AI)* are:

- opportunity to use bulls of superior genetic composition
- reduces threat of venereal disease
- lessens possibility of delayed conception caused by sterile sires
- permits the use of more than one bull or breed in breeding programs

- generally less expensive to use AI than to purchase and keep a top-quality bull throughout the year.

* The information on AI was taken from Alberta Agriculture's Extension files, p. 38.

BIOLOGICAL CONTROLS

In Science 10, Unit 2, Major Concept 4, when investigating the positive and negative features of commonly used systemic pesticides, consider the use of biological controls in agriculture. One such biological control is the triploid grass carp being studied at the Lethbridge Research Station. These sterile carp may eventually be used to rid irrigation canals of weeds. Have the students evaluate the advantages and disadvantages of releasing carp into the canals. What would happen if these carp manage to escape the canal system and get into a reservoir or lake? Will scientists be able to develop reliable means of keeping the carp in designated areas of irrigation canals? Could they use sonic barriers? The background paper on this topic, "Triploid Grass Carp Research in Alberta", prepared by the Committee on Biological Control of Aquatic Vegetation, is available from E. D. Lloyd, Chairperson, phone 381-5539. The idea of sonic barriers came from *Alberta Agriculture Research Report*, volume 5, number 2, November 1990.

HEAT ENERGY

In Science 10, Unit 1, Major Concept 2 relate Alberta's different growing seasons to the amount of solar energy absorbed at the different latitudes. Southern Alberta receives more "heat units" (energy) than northern Alberta. The type of crops we grow in each area depends on the number of heat units available. For example, sunflowers and sweet corn are much more successful in southern Alberta.

Within the same unit, you can calculate the amount of heat energy absorbed or released using the formula $Q = mc\,(T_2 - T_1)$. On cold winter days, farmers would place 30 L pails of water in their root cellars. As the temperature of the water drops and starts to freeze, it gives off energy in the form of heat. This heat is enough to keep the vegetables from freezing. Ask the students to calculate the amount of energy loss by 30 L of water at 31°C if the final temperature was 1°C.

$$Q = mc\,(T_2 - T_1)$$
$$Q = (30\text{ kg})(4.19\text{ kJ/kg°C})(31.0\text{°C} - 1.0\text{°C})$$
$$Q = (30\text{ kg})(4.19\text{ kJ/kg°C})(30.0\text{°C})$$
$$Q = 3771\text{ kJ}$$

In Chemistry 30, Unit 1, you can calculate the enthalpy changes associated with physical and chemical changes to matter in agriculture. A phase change occurs when you add ammonia to water to make a fertilizer solution. This phase change is endothermic.

RESOURCES FOR AGRICULTURE IN THE CLASSROOM

As you begin or continue using agriculture contexts in your science classroom, there are many support resources you can turn to.

The Business of Agriculture, Science 10, 20, 30

This handbook, produced by Alberta Agriculture, is intended as a teacher reference for lesson planning. For example, Activity 11, "Down in the Nutrient Valley", is a class exercise that discusses the theories behind biodegradable plastics.

Agriculture Ambassador Program

If your school has joined the Agriculture Ambassador network, speak with the Agriculture Ambassador. He/she has access to current information about agriculture resources in the form of lesson plans, printed material, audio-visual material and guest speakers/special program lists. The ambassador can call on resource people from the Agriculture Ambassador's Speaker's Circle. These speakers will be available to give workshops and information sessions during professional development days or special meetings. Agriculture in the Classroom is trying to ensure that every school in the province is represented by an ambassador. If your school does not have one, take the initiative to send the name(s) of a nominee(s) to Agriculture in the Classroom.

Summer Agricultural Institute

This program is an intense two-week course that exposes teachers of all subject areas and grade levels to agricultural topics and information that can be used in the classroom. For further information contact:

Agriculture in the Classroom Program
Alberta Agriculture, Education Branch
J.G. O'Donoghue Building
2nd Floor, 7000 – 113 Street
Edmonton, Alberta T6H 5T6
Telephone: 427–2402

The Research Report

This is an excellent publication of the Research Division of Alberta Agriculture. It is published ten times a year, and can be obtained free of charge by writing to:

Alberta Agriculture
Research Division, Research Report
202, J.G. O'Donoghue Building
7000 – 113 Street
Edmonton, Alberta T6H 5T6
Telephone: 427–1956

Just Facts

This is a useful package of fact sheets produced by the Alberta Cattle Commission:

216, 6715 – 8th Street N.E.
Calgary, Alberta T2E 7H7

Hanging Files

Clip articles relevant to agriculture from newspapers and magazines and place them in a folder. You never know when you can make use of them.

TECHNOLOGY AND MEDIA

by Dave Jordan

The following is a guide for choosing and using media in various types of learning situations, with particular emphasis on science. It is designed to help the teacher use media in the teaching situation as well as to encourage the use of media and technology by students – to enhance their observation, analysis and communication skills.

Teacher backgrounds in the use of media and technology are very diverse.

Teacher backgrounds in the use of media and technology are very diverse. The following material provides basic information, while the resource list provides references for more in-depth exploration.

WHAT ARE MEDIA AND TECHNOLOGY?

In the process of creating effective learning environments we use a wide variety of media and technologies as teacher aids. Videotape, video laserdiscs, slides and computer programs all contain messages and concepts that are delivered with the assistance of their associated technologies.

To retrieve and use the programs (content), it is essential to have the medium (film) and use the technology (film projector).

Why are media and technology important in science teaching?

Teachers recognize the variety of ways in which students learn. Students learn through using their senses – the greater the number of senses used, the more the experience is enriched and reinforced, leading to greater internalization of the experience on the part of the observer.

Hearing and seeing a phenomenon is a prelude to the activities a student undertakes for a more complete understanding of any situation.

There is an old saying . . .

> Tell Me – I Hear,
> Show Me – I See,
> Let Me Do It – I Understand!

Hearing and seeing a phenomenon is a prelude to the activities a student undertakes for a more complete understanding of any situation.

Some students prefer learning through listening and some through manipulatives. Others are oriented toward visuals and visualizations of phenomena. They translate concepts and processes into visual equivalents, which are then manipulated mentally.

Media, operating through various technologies, provide the audio and visuals that can better support different styles of learning. Media can offer a diversity and intensity of learning possibilities greater than an individual teacher can provide.

Through well-chosen programs, students are able to view reconstructions of times, places and events, many of which only art and/or computer simulations can illustrate.

Through well-chosen programs, students are able to view reconstructions of times, places and events, many of which only art and/or computer simulations can illustrate. They may also run computer simulations for events that would normally take micro-seconds or billions of years. Through video programs on tape or laserdisc, students are able to retrieve and use visual data produced by super-computers, speed up time and examine the warping effects produced when galaxies collide. With the slow motion capabilities of tape or disc they may slow down time and observe the changes in a cell as it divides.

With the increasing availability of multimedia to the student, the teacher must be aware of the motivational advantage of using media and technologies to meet educational objectives.

Unfortunately, some teachers approach media with an attitude that multimedia use is a frill, or that they must compete with it. It is extremely difficult to compete with products that were designed and developed with the cooperation of many experts in a variety of fields.

Teachers can effectively use media and turn their advantages into advantages for their students. The media-conscious teacher becomes a facilitator of learning, picking and choosing the appropriate media, time and circumstances to maximize learning opportunities. This teacher analyzes the curriculum and orchestrates all components to produce a learning system that stimulates and encourages scientific thinking. The teacher takes advantage of all available resources and organizes them in a manner that supports acquisition of the required knowledge, skills and attitudes of the curriculum and its extensions.

Media provide the teacher with an arsenal of approaches and techniques that help ensure that the message is received or correctly interpreted. Media are not only motivating, but provide in-depth experiences that serve to present the concept, enhance its understanding, reinforce it and test for its effects.

However, here is a word of caution. Media and technologies should not be used to eliminate real-life experiences when these experiences are not dangerous or do not require a number of resources.

Media and technologies should not be used to eliminate real-life experiences when these experiences are not dangerous or do not require a number of resources.

As an example, consider a television program used to demonstrate the pendulum, and how the frequency of the pendulum depends on the length of the string. Because of the simple nature of the pendulum, students can create their own by using string and a small object. The basic concept can then be seen and appreciated in real life. To get the student into the physics and mathematics of the concept, the student may use a video camcorder to record the pendulum's swing, then use slow motion for analysis. The student may then use a computer program to analyze the mathematics and determine the actual equations.

Also, media should not be used to replace once-in-a-lifetime opportunities that have immense impact on students' attitudes toward science. A prime example of the misuse of media occurred during the 1979 total eclipse of the sun, visible across much of North America.

Many schools in the path of the eclipse kept their students in darkened classrooms and had them watch the event on television while the real event happened outside! Others carefully prepared their staff and students to observe the spectacle safely and provided an excellent opportunity for students to learn about the causes of eclipses, the sun and its dangerous radiations. Students learned how to observe the sun safely and built simple but effective observation apparatus.

Many teachers did not take advantage of this unique opportunity and its vast media support to undertake a number of learning experiences that would have highly motivated their students in science. A total solar eclipse is a scientific event that stirs the soul, but watching the eclipse on television relegates it to another common everyday experience. Observing the real event provides an immeasurable degree of scientific motivation and a unique memory that lasts a lifetime.

A total solar eclipse is a scientific event that stirs the soul, but watching the eclipse on television relegates it to another common everyday experience.

Media and technology have an important place in the learning situation, but they must not be used to replace real-life experience! How can teachers encourage the use of media and technologies by their students?

Many contemporary technologies such as still cameras, videocameras and other video/computer equipment are now very user-friendly.

The processes of science are supported through the use of technologies that assist in the observing, recording, analysis and evaluation of data. With the incorporation of various technologies, the learner is able to make more effective and efficient use of time and gain a much greater understanding of the phenomena being observed, as well as an understanding of how they are integrated into other areas of life.

Recording scientific events is now possible through photography, videography, audiotape and computer sensors. Access to related information may come through film, slides, videotape, video laserdisc or computer programs. Analysis may be done with pencil and pad or by computer graphing. The student can present information using any audio-visual technology supported with printed materials.

Many contemporary technologies such as still cameras, videocameras and other video/computer equipment are now very user-friendly. Most students will have had some experience with this equipment and will have no problem using them in science-based situations.

The teacher who is aware of the many advantages of using media and encourages their use, knows students who use media are more involved in the learning process and the applications of skills in areas other than those directly related to the learning situation.

Using Media in the Science Inquiry Process/ Technological Problem Solving/Research

Recording Data

Students may apply various types of technologies to obtain and process data.

Some processes, such as cell division, are very visually oriented, and may not provide hard mathematical data. For this type of situation, it is preferable that data be gathered through the use of cameras, still or video, and that the data be available for review if and when desired. The storage of this type of process on video also has the advantage of fast or slow motion to locate and observe transient phenomena. The recording of such data also allows the data to be shared with others in a review or presentation situation.

Still cameras provide a permanent, high-quality record of an event. Recording the event on video provides a record of moment-to-moment changes. The video camera allows for later detailed, time-based analysis.

Computers may also be used to record data such as temperature, light intensity or sound changes. They do this through sensors that are linked into the computer, with the status of the sensor being sampled at a certain rate. This time-based sampling then produces the data, which are stored in the computer. The data may then be saved as a file and retrieved for analysis.

Using a computer for data gathering has the advantage that it is objective and can gather data over very long or very short periods of time.

Using a computer for data gathering has the advantage that it is objective and can gather data over very long or very short periods of time. The data can also be stored and transmitted via telephone lines, if necessary, over long distances. In a classroom situation, data gathering via computer is an introduction to the way in which much contemporary science is done in the "real world". It also provides a teaching/learning opportunity in which the student can learn about the computer and its sensors, rates of data acquisition, data storage, retrieval, analysis and transmission. It also provides an opportunity to those who are computer-oriented to apply that knowledge in the field of science.

Kits are available that use temperature, motion, pH, and light sensors. Called "science tool kits", they can provide an excellent tool when students are challenged to design and build experiments that use sensors to collect data.

<u>Organizing and Analyzing Data</u>

Data analysis is qualitative or quantitative. For qualitative information, the still camera or videocamera has the advantage of a permanent record to which the student or teacher may refer at any time.

The use of computers is not intended to eliminate understanding of the process, but to allow more time for the most important aspect of the scientific process – thinking!

Data analysis may also involve the use of quantitative information from a variety of sources. The student is often required to gather the data, organize it, then analyze it. This process usually involves the use of tables, charts and graphs. Some of this tedious, time-wasting activity may be eliminated by using computers. They may be used to gather the data (sensors), store the data (as a file) then produce tables or graphs. This has the advantage of providing the student with more time to analyze the data and research-related concepts. The use of computers is not intended to eliminate understanding of the process, but to allow more time for the most important aspect of the scientific process — thinking!

Computer data base or spreadsheet programs support scientific learning by providing easy, rapid access to all types of data, allowing easy organization or manipulation of data and production of graphs of all types. This leads to increased understanding of the event, and application of general principles to specific situations.

For example, a data base program will allow the user to order by size all the planets and moons in the solar system.

Data base programs allow the student the luxury of examining the relationship between events, objects or their attributes. For example, a data base program will allow the user to order by size all the planets and moons in the solar system. It will also allow the user to take a select group, all moons for example, then order these according to size or density. In this way, the student is exploring relationships for understanding, and developing information operation skills that he or she can apply to all areas.

Spreadsheet computer programs allow the user to ask the question "What if . . .?" and manipulate data in many ways while seeking answers to a variety of questions. As an example, the student can use a spreadsheet program to change one variable by various amounts, seeking one value that will produce the desired change in other variables.

Computer simulations allow students to explore a concept and come to certain conclusions based on the outcomes the computer generates.

Computer simulations are another area in which the student can use the computer to gather qualitative or quantitative data. Simulations allow the user the opportunity to explore the effects of changing certain parameters on a system that is modelled on the real world. For example, a simulation may include introducing certain types of predators into a biosphere and observing the results on a prey population. Another example might be changing the mass of an object and watching its effects when in collision with another object.

Computer simulations allow students to explore a concept and come to certain conclusions based on the outcomes the computer generates. They are usually more cost-and-time effective than using real objects, and may be more accurate than student-made measurements of real events.

Students may also use the computer and modem to gather data from distant electronic bulletin board systems and data bases. All that is required is a modem, software program and the telephone number of the remote computer, as well as the code to access the information. These systems are invaluable in that students are not only able to acquire all types of data from anywhere in the world, but can also interact with professionals in many different fields.

Presenting Data

Once the student has had a chance to acquire, organize and analyze data, it will usually be necessary for him/her to present the results.

Again, the student may choose from a wide variety of media and technologies to present his/her findings. He/she may wish to introduce the topic area through selected clips from films, videotapes or video laserdiscs. The student may then provide a printed copy of the report produced by a computer word processing program. The presentation may also include charts and graphs produced by the computer and presented on overhead transparencies. If an overhead projection pad is available, the student may wish to run some simulations for the audience, illustrating the effects of various inputs into the program. When concluding, the student might support his/her findings by again referring to video or film clips and perhaps slides.

STRATEGIES FOR MEDIA/TECHNOLOGY INTEGRATION

1. Identify Curriculum Supporting Materials

- use the teacher resource manual as a reference in identifying materials directly related to the concepts, attitudes and skills being presented.

Teachers should encourage their students to:

- design and develop their communications, using various media (use videotaped segments to support class reports; use the computer and projection system to present simulations and results, etc.)
- record, retrieve, review and evaluate information related to science projects or classroom presentations (use the computer and sensors to produce data files, graphs, graphics, etc; obtain relevant information from videotape, videodisc, audiotape, etc; store gathered information through videotaped interviews, running segments derived from other sources, etc.)
- ask the librarian or other teachers for leads on materials that may be effective in teaching the concept.

2. **Locate and Retrieve the Material**

- use both traditional and electronic indexing systems such as CD-ROM to locate references
- use electronic encyclopedia and bulletin boards, reference lists, hanging files and periodicals to locate relevant, current information
- ask the school librarian for assistance in locating and retrieving the desired material or materials that may be equally effective. The librarian is most familiar with procedures to obtain materials in your school. Students may be involved in this process as well.

3. **Evaluate the Material**

Basing the use of material on title or general description alone can be the forerunner to some very embarrassing or counterproductive situations.

The material must be reviewed by the teacher before use with students. This step cannot be emphasized enough! Basing the use of material on title or general description alone can be the forerunner to some very embarrassing or counter-productive situations, and every staff room has stories to support this point.

This most important step must answer several questions. The following points should be applied to the material to evaluate its possible use in the classroom:

- the material is current
- the message is clear in intent
- all components are easy to understand (level)
- the material is presented in a logical manner
- the material is presented at a reasonable pace
- the material is presented in an artistic manner
- the subject is presented from the best perspective for understanding
- components present the subject in a positive light (Tolerance and Understanding characteristics)
- components use unique approaches to present the subject
- a multiformat presentation is used to reinforce understanding

THE FUTURE OF MEDIA AND TECHNOLOGIES IN EDUCATION

The advent of low-cost, user-friendly, powerful computers combined with the pervasive use of all types of media is making for very exciting future prospects in media and technology. Much of our work, play and communications will be done on general-purpose work stations in the near future. These generic stations will allow the user access to all forms of communications -- telephone, fax, videophone and computer modem — while also allowing access to myriad television channels, video laserdisc and other laserdisc-based programming for viewing or interaction.

The increasing trend by large, multinational companies to promote world-wide communications standards will provide for reductions in hardware, software and communications costs while allowing for increased communications capabilities. The inclusion of high speed, powerful computer chips in the home work station will provide the user with all of the capabilities contemporary computers or multimedia systems have, and more.

The increasing trend by large, multinational companies to promote world-wide communications standards will provide for reductions in hardware. software and communications costs while allowing for increased communications capabilities.

Advances in technology have created new ways of approaching information of all types. Multimedia and hypermedia approaches now allow the user to explore an unlimited number of avenues in learning. The challenge to the user is to use learned skills to handle the wealth of information and cull those items that are current, relevant and useful. Educators must become familiar with these advances and their techniques, then develop approaches in teaching/learning that will provide the student with the necessary skills.

The challenge to the user is to use learned skills to handle the wealth of information and cull those items that are current, relevant and useful.

We live in a society where the acquisition, organization, analysis and presentation of information is of paramount importance. These operations are more and more oriented toward multimedia approaches for all aspects of the process. It is only through using multimedia and encouraging their use among students that we acquire much of this knowledge. It also bodes well for the continued interest of students in all areas of science.

Changing lifestyles will see more people working at home and, with this trend, powerful multimedia work stations will become the standard. Educational changes will be necessary to reflect this approach to living and working in the future.

The greatest challenge to educators will be to change their roles; become facilitators of the learning process. This means increased awareness of new media and technologies and how these may be adopted and adapted to meet educational needs. It also means taking a more aggressive role in using these technologies to support and promote the process of learning in an era that sees us deluged with information of all types and quality.

A SUGGESTED APPROACH TO USING MEDIA AND TECHNOLOGIES

Aspects of data acquisition and controls must be discussed to ensure that the results are of good quality.

The following is one approach to using media and technologies to teach a major concept and related concepts in science. The teacher's role is more that of a learning facilitator, directing and organizing learning opportunities.

Major Concept: Weather systems are driven by energy from the Sun.

Introduction: The concept is introduced through two experiments.

Students are first asked to consider the energy coming from the Sun and its effects on materials on Earth. Students are then asked to devise simple experiments to gain data on this energy. Aspects of data acquisition and controls must be discussed to ensure that the results are of good quality. Students are asked to hypothesize about the results and what the graph will look like.

The first experiment consists of placing a measured amount of water into a can that has been painted black. The can is placed in the sun and the temperature of the water is determined by taking readings at set intervals. These readings may be taken by a regular thermometer or by a computer using a thermocouple. The data are then graphed, with pen and graph paper or by computer.

The second experiment uses two cans, one painted black, the other white, with equal amounts of water. Again, controls must be considered and students asked to hypothesize as to the results. Data are gathered by thermometers or computer sensors. Other experiments are discussed and will be carried out.

The results of the experiments are discussed in the following context:

- energy is absorbed from the Sun by materials on Earth
- the amount of energy absorbed may be measured by increases in temperature
- energy is absorbed by materials differentially depending on their colour, reflectivity or energy absorption characteristics.

In discussion, the above points are used to lead into the following questions, project design, reports, presentations, demonstrations, guest presenters, etc. The students are to plan their projects carefully to include research through all types of media, collect data through all possible means, and use computers, video and other means to collect and collate the data, organize it, prepare reports and present their findings.

The students are to plan their projects carefully to include research through all types of media, collect data through all possible means, and use computers, video and other means to collect and collate the data, organize it, prepare reports and present their findings.

a. the types of energy provided by the Sun in reference to the spectrum

   - what is a spectrum?
   - what does the spectrum of the Sun contain in terms of types of radiation?
   - what is the infrared part of the spectrum?
   - how do we measure infrared energy?
   - what instruments are used to detect and measure infrared energy?
   - how do these instruments work?
   - how are they applied to problems in science and society?
   - how can infrared energy be used in photography, videography, astronomy, etc.?
   - how can these principles be applied to designing clothing, buildings, landscaping, etc.?
   - develop a portfolio of clothing types used in various parts of the world with different temperature extremes
   - what may be learned about the styles, colours, etc., related to energy use?
   - analyze a spacesuit and what needs are fulfilled by its design
   - analyze the school and schoolyard and evaluate its use of solar energy and landscaping principles
   - redesign the school and schoolyard to take advantage of the principles learned
   - build a model of a home that uses active and passive solar energy.

b. the effects of sunshine on Earth

- differential heating depending on the reflectivity of the surface
- differential heating based on latitude
- transfer of energy throughout Earth by prevailing winds
- weather the effects of differential heating of air currents, winds, hurricanes, tornadoes, etc.
- what technologies are used to measure Earth's heating by the Sun? (satellites, weather balloons, weather stations, etc.)?
- how do these technologies work?
- how are their results used on a daily basis by society?

From the student's perspective, the following sequence of activities could take place:

The student undertakes the experiments, taking notes that are then compiled in a report using a computer word processor. The experiment is videotaped to show the set-up, the time and readings. The data gained from the experiments are entered into a computer data base, which is used to prepare graphs of the results.

The student can begin research into assigned or preferred topics of his or her choice. Using a computer and CD-ROM encyclopedia, the student may locate information on the Sun, infrared energy, energy production, absorption, etc. The student may dump sections from each of these CD-ROM encyclopedic segments into a word processor on the computer and obtain a printout that will be used as part of the research..

The student may also review a number of videotapes on the Sun, its radiation and its effects on Earth and its weather. The Sun and its attributes may be further explored through a video laserdisc, and specific frames or running segments noted for later use in a report and presentation.

The fax may be used to request and receive information from various companies involved in technologies.

The student may also explore the various technologies used in detecting and measuring infrared and other radiation through print, electronic encyclopedias, experiments and field trips. As well, the fax may be used to request and receive information from various companies involved in technologies related to this area.

The student may also investigate the effects of the changing seasons on the amount of radiation received by Earth by requesting from the federal weather office (using the fax), temperature readings for a year. This investigation may also be supported by using a computer program that calculates the Sun's angular altitude for any time of the year. Once these two sets of data have been received, they may be entered into a computer data base and the two graphs overlayed and compared. Review of local printed, radio and television weather reports is also a consideration.

Experiments should be designed and undertaken to obtain data at the local level. Comparisons should be run with federally obtained data, discrepancies noted, hypotheses prepared and discussions undertaken with various types of resource people, including Environment Canada scientists.

Computer- and mathematics-oriented students can design and write a computer program in BASIC (or another language) that models the effects of varying angles of the Sun and energy absorption characteristics of a material. This simulation may then be used to assist in the design of model schools or homes.

Students should undertake direct communication via telephone, fax, or in person, with scientists responsible for taking measurements, with a view to obtaining access to equipment, data, advice, field trips and cooperative ventures.

Reports to the class on projects should be prepared on computer word processing and desktop publishing systems. As well, the presentation should include the use of computer-prepared overhead transparencies, computer graphics and video segments from videotape, video laserdisc and camcorder. The entire project could be planned so that all pertinent audio-visual information is edited onto a videotape and accompanied by the printed section of the report.

Reports to the class on projects should be prepared on computer word processing and desktop publishing systems.

TRADITIONAL AND LOCAL KNOWLEDGE

from the Junior High Science Curriculum Document, NWT Education and Dr. Gloria Snively (reprinted with permission)

Science is knowledge obtained through observation and experience. It is one way of looking at the world. Societies everywhere have different ways of interpreting the world around them. How a people perceive their world is called a **worldview**.

Western science is just one worldview which tries to understand the world using the scientific method. The scientific method refers to a series of steps used by scientists to obtain knowledge about a particular problem. Western science developed out of the traditional science of Europe.

*How a people perceive their world is called a **worldview**.*

What Is Traditional Knowledge?

Traditional science or traditional knowledge refers to the worldview of peoples who do not adhere to the western scientific tradition.

Traditional knowledge is an interpretation of how the world works from a particular cultural perspective.

Traditional knowledge is built up by a group of people through generations of living in close contact with the land. It is based upon their observations and experiences.

Traditional knowledge is usually transmitted orally, and is often in story form.

Traditional knowledge includes knowledge about plants, animal behaviour, hunting rules and the way people should behave towards each other.

Examples of Traditional Knowledge

Traditional knowledge might include:

- hunting practices which ensure conservation of wildlife
- preparation and design of clothing, food and tools
- traditional medicine
- aboriginal classification systems of natural and social environments
- aboriginal taxonomy within the classes of plants and animals

- traditional knowledge of plants and animals (uses, life cycles, interrelationships)
- historical perspective on traditional harvesting
- aboriginal concept of sustainable development
- a view of humans and nature being inseparably linked.

What Is Local Knowledge?

Local knowledge is knowledge which people have today about their present surroundings which may or may not be based upon traditional knowledge. For instance, local knowledge could be information about changes in the migration routes of caribou as a result of new land use activities.

Fostering of Attitudes

The inclusion of traditional and local knowledge develops in the student:

- a positive concept of self, community and culture
- an awareness of values and customs
- attitudes of cooperation and respect
- an understanding of cultural and linguistic diversity.

Differences and Similarities Between Western and Traditional Science

One of the main differences is that western science is written down while traditional science is generally oral.

Both western and traditional science try to understand how the world works. Both types of science use observation and experimentation to obtain knowledge. One of the main differences is that western science is written down while traditional science is generally oral. Western science tends to be more quantitative (concerned with exact numbers and measurements). Results are usually expressed in numerical form. Traditional science is more qualitative (concerned with describing changes in relative terms – more/less, faster/slower rather than with precise numbers). Western science tends to be more mechanistic in its approach, dividing the world up into parts and studying them individually. Spirituality and social life are seen as being separate from nature. Humans are believed to dominate and control nature. Traditional science tends to be more holistic, viewing the world as one interconnected whole. Spirituality, social life and nature are all dependent upon each other. Humans are not regarded as being more powerful or more important than nature.

Advantages of Western Science and Traditional Science

Western science has the advantage of being able to examine living and non-living things at the microscopic level. Scientists can also compare data over greater distances and with scientists in other parts of the world.

Traditional science has the advantage of being able to examine a particular area closely over a long period of time. People who have lived on the land for generations have an intimate knowledge of the habits of wildlife. They observe animals during all seasons over a period of many years. Many biologists who study animals often remain on the land for only a short period of time, often during the summer only, so they do not have the benefit of long-term observation.

Suggested Approaches to Gathering Traditional/Local Knowledge

- community-based research projects
- interviews
- biographies of elders
- field trips
- contacting associations, institutes and organizations.

Sources of Local Teaching and Learning Resources Related to Traditional/Local Knowledge

- maps, photographs, taped stories
- biographies/life histories
- films, videos, filmstrips
- museums, cultural institutes
- elders, classroom assistants
- resource people from the community
- various government departments
- Native language magazines and periodicals
- pamphlets and booklets from Native organizations and agencies
- Native members of school staff
- Parks Canada staff
- local TV and broadcasting stations

It is possible and even desirable to explore the different perspectives each tradition generates during instruction, particularly if traditional categories for flora, fauna, habitats and relationships can be correlated with scientific analogies of the same phenomena.

Teachers can allow for participation and a sense of how a common environment can be viewed from different orientations, or a combination of orientations.

What Does Research Say?

The current research suggests that the two traditions – Native oral tradition and western scientific thought – in combination provide a broader perspective than can either by itself. It is possible and even desirable to explore the different perspectives each tradition generates during instruction, particularly if traditional categories for flora, fauna, habitats and relationships can be correlated with scientific analogies of the same phenomena. Teachers could develop lessons around the traditional beliefs and values of the Native community, the scientific views, and the similarities and differences between them.

As science educators we must not forget that our overall task is not simply to present science concepts – as if this were a detached task – but to present an authentic view of science and to set science education in a social and cultural context.

Young persons in small communities have many rich experiences for the teacher to draw on. Many have helped their parents or grandparents from the age of five or six. Many will know a lot about traditional stories, food gathering and preparation, medicinal herbs, songs and dances. By age ten or twelve, many will have had experience with motor boats or small machines and know a lot about navigation, carpentry, and mechanics. Many will have experienced drawing traditional figures, carving animal figures, and other various forms of traditional artwork.

Teachers could develop lessons around what students experience and talk about in their community. Teachers can allow for participation and a sense of how a common environment can be viewed from different orientations, or a combination of orientations. This will help alleviate alienation which is common to those who cannot participate fully in what has become the typical science classroom.

Integrating Western Science and Traditional Science into Lesson Planning

The following considerations must occur:

- Oral traditions, folk tales, myths and legends must be respected and viewed by the teacher as distinctive intellectual tradition, containing their own implicit truths .
- No textbook can comprise a viable science program for culturally different students.

- The spiritual stories and heritage of the Native community should become part of the school science experience.

- Science teaching strategies cannot be the same for each school or classroom. The strategies must be modified to take into account the social and cultural qualities of the community (Cruikshank, 1981; Beck, 1982; Wangler, 1983).

It is possible to increase a student's knowledge of scientific knowledge without altering substantially his or her preferred orientation.

- It should be part of science teaching that students be given the opportunity to reinterpret new information in light of their own orientations. Students should be given opportunities to identify and articulate their own orientations with others in small group situations.

- Students need to know that what they have to say is important, no matter how far the content deviates from the science concepts as perceived by the teacher. This allows opportunities to meet individual student needs and interests, as well as promote feelings of self-worth.

- It must be recognized that there are many interpretations of natural phenomena, just as there are many interpretations of religion, politics, economics, or art.

- It is possible to increase a student's knowledge of scientific knowledge without altering substantially his or her preferred orientation. We can increase a student's scientific knowledge so that it can be utilized in appropriate situations. It makes sense to talk about increasing a student's knowledge and changing certain alternate beliefs and science concepts. It makes sense to talk about using the student's preferred orientations as bridges to teach science concepts.

- Since it is likely that prior knowledge exists as a consequence of culture and personal beliefs and theories, then different groups will likely have different prior knowledge and alternative conceptions which need to be discussed during instruction.

- When a particular scientific view is presented in the classroom, a student's cluster of prior ideas, beliefs, values and emotions serves as the initial set of interpretative categories, and it is the potential match between these existing cognitive commitments and the new information which determines how the student will respond to the instructional inputs.

REFERENCES

Beck, B. 1982. "Root Metaphor Patterns." (Review of *Metaphors We Live By* G. Lakoff and M. Johnson. Chicago: University of Chicago Press, 1980). *Recherches sémiotiques/Semiotic Inquiry* 2(1):86–87.

Cruikshank, J. 1981. "Legend and Landscape: Convergence of Oral and Scientific Traditions in the Yukon Territory." *Arctic Anthropology* 18(2): 67–93.

Pepper, F. and S. Henry. 1986. "Social and Cultural Effects of Indian Learning Styles: Classroom implications." *Canadian Journal of Native Education* 13(1): 54–61.

Wangler, D. 1983. "Science, Nature and Man: A Brief Investigation of the Art of Knowing as Practiced by Scientific and Non-scientific Cultures." *Canadian Journal of Native Education* 11(1): 46–51.

Whyte, K. 1986. "Strategies for Teaching Indian and Metis Students." *Canadian Journal of Native Education*, 13(3): 1–20.

TEACHING WITH A GENDER BALANCE

by Jennifer Smith

". . . schools are important agents of socialization, . . . those who wish to change society frequently suggest that education will be their vehicle."

(Delamont, 1980, p. 3)

THE FACTS

According to the 1981 Canadian census, the percentage of women employed in the natural sciences and engineering was 48%. Refer to Table 1. At first glance, this is encouraging — it's not unreasonable to expect half the participation from half the population. However, if we examine this occupational group more closely we see that a disproportionately large number of women were in the medicine and health professions, and the overwhelming majority were either nurses or lab technicians.

Table 1:
Scientists, Engineers and Technologists by Occupational Group and Sex

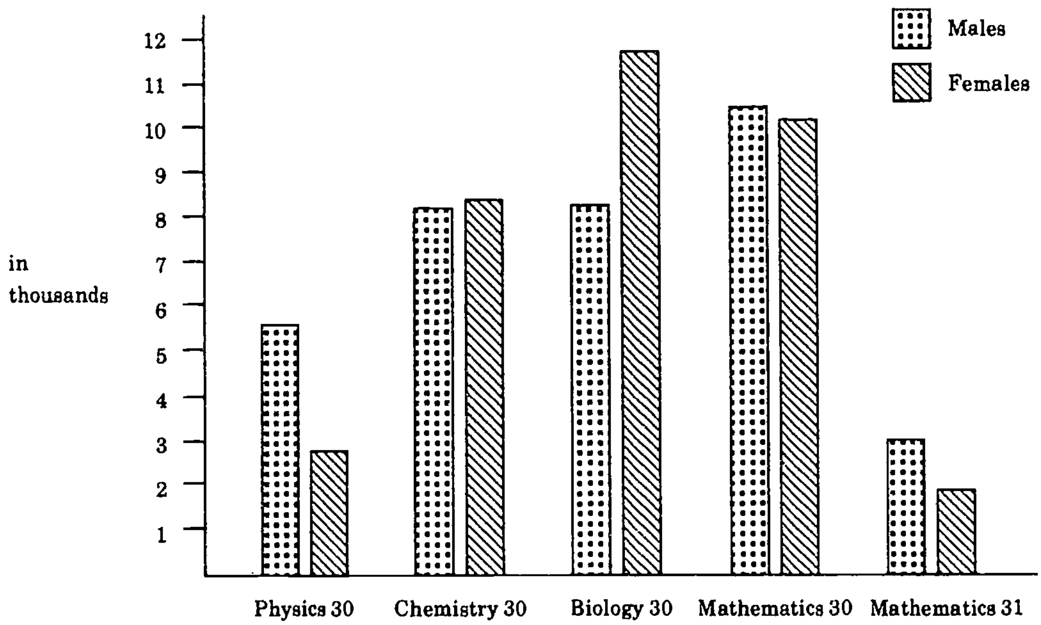
OCCUPATIONAL GROUP	1971			1981		
	M	F	Total	M	F	Total
	(in thousands)					
NATURAL SCIENCES AND ENGINEERING...	290 (54.2%)	245 (45.8%)	535 (100%)	454 (52.0%)	419 (48.0%)	873 (100%)
Medicine and Health...				122 (25.0%)	366 (75.0%)	488 (100%)
Mathematicians and Statisticians...				46 (69.7%)	20 (30.3%)	6 (100%)
Life Sciences...				20 (76.9%)	6 (23.1%)	26 (100%)
Physical Sciences...				31 (81.6%)	7 (18.4%)	38 (100%)
Architects and Engineers related...				104 (89.7%)	12 (10.3%)	116 (100%)
Architects and Engineers...				131 (94.2%)	8 (5.8%)	139 (100%)
Eliminate "Medicine and Health"	208 (93.3%)	15 (6.7%)	223 (100%)	332 (86.2%)	53 (13.8%)	385 (100%)

Source: Statistics Canada, *Science and Technology Indicators 1985*, Table 1, p. 180.

The high participation of women in occupations related to medicine and health offsets the impact of the other five occupational subgroups in which women are under-represented. Of the five subgroups, the highest female representation is in the "mathematicians and statisticians" category (30.3%), and the lowest percentage falls into the "architects and engineers" category (5.8%). By excluding health sciences from the other occupational groups, the mean percentage of females employed in the natural sciences and engineering drops dramatically to 13.8%! However, this figure has doubled since 1971 when the same mean per centage was 6.7%.

What is the situation in high school? In Alberta, the ratio of males to females who wrote the 1989 Grade Twelve Diploma examinations in science and mathematics was nearly equal. Further analysis shows a relatively high number of females in Biology 30, Chemistry 30 and Mathematics 30 compared with Physics 30 and Math 31. Refer to Table 2.

Table 2:
Number of students writing Science and Mathematics Diploma Exams in 1989



Source: Student Evaluation Branch, Alberta Education

Table 3, outlining required and recommended courses for entrance to the Bachelor of Science Honours and Specialization Programs at the University of Alberta, indicates that if either the Physics 30 or Mathematics 31 requirement is not met, the choices of programs available to students would essentially be limited to three out of a possible 24! Clearly, we must encourage science-oriented high school students to complete all three sciences—biology, chemistry and physics—as well as Mathematics 31, so as not to restrict their program and career options.

Table 3:
Subject Requirements for BSc Honours and Specialization Programs

(In addition to English 30 and Mathematics 30)

Programs of Study	Honors	Special.	Biology 30	Chemistry 30	Physics 30	Math 31	Advising Department
Applied Mathematics	H				X	X	*Mathematics*
Biochemistry	H	S	X	X	X		*Biochemistry*
Botany	H	S	X	X	R		*Botany*
Cell Biotechnology	H	S	X	X	R		*Microbiology*
Chemistry	H	S		X	X		*Chemistry*
Computing Science	H*	S*			X		*Computing Science*
Entomology	H	S	X	X	X		*Entomology*
Genetics	H	S	X	X	R		*Genetics*
Geography	H	S					*Geography*
Geology	H	S		X	X		*Geology*
Geophysics	H	S		X	X	R	*Physics*
Mathematical Physics	H				X	X	*Physics*
Mathematics and Economics	H	S			X	X	*Mathematics*
Mathematics	H	S			X	X	*Mathematics*
Meteorology		S			X	R	*Geography*
Microbiology	H	S	X	X	X		*Microbiology*
Paleontology	H		X	X	X		*Zoology*
Pharmacology	H*	S	X	X	X		*Pharmacology*
Physical Geography	H	S					*Geography*
Physics	H	S			X	R	*Physics*
Physiology	H		X	X	X		*Physiology*
Psychology	H*	S					*Psychology*
Statistics	H	S			R		*Statistics*
Zoology	H	S	X	X	X		*Zoology*

X – Required R – Recommended *No Direct Entry to First Year

Source: University of Alberta, *Admissions*, 1991, p. 17.

At the post-secondary level, the picture is much the same. Enrollment statistics for first year undergraduates attending Alberta universities in 1989/90 are outlined in Table 4. The lowest participation by females was in the programs of Engineering, Dentistry, and Medicine with the highest participation in Dental Hygiene, Nursing and Medical Lab Science. Females opted out of the science professions to which society attaches a higher status, with accompanying higher salaries. For example, women selected Dental Hygiene (95% female) rather than Dentistry (32% female), and Nursing (95% female) rather than Medicine (39.7% female).

It has been projected that a large proportion of employment opportunities in the next century will be based on science and technology.

Table 4:
Enrollment of First Year Undergraduates Attending Alberta Universities By Sex and Degree Sought

	Male		Female	
B.Sc. (Hon.)	86	(64.7%)	47	(45.3%)
B.Sc. (Gen.)	852	(53.6%)	738	(46.4%)
B.Sc. (Eng.)	747	(93.3%)	103	(6.7%)
B.Sc. (Pharm.)	64	(57.1%)	48	(42.9%)
B.Sc. (Nursing)	11	(5.0%)	211	(95.0%)
Medicine	117	(60.3%)	77	(39.7%)
Med. Lab Science	4	(15.4%)	22	(84.6%)
Dentistry	34	(68.0%)	16	(32.0%)
Dental Hygiene	2	(5.0%)	40	(95.0%)
M.Sc.	511	(66.0%)	263	(34.0%)

Source: U of A *Summary of Statistics* 1990/91, U of L *Facts Book* 1988/89, U of C *Fact Book* 1989/90

THE IMPACT

We are in the midst of a technological revolution, making it essential to develop a scientifically literate population (Science Council of Canada, 1984). Decisions must be made to determine the direction new technological advances should take; it is imperative for women to have an equal say in this decision-making process. The current 13.8% participation rate of Canadian women in technical fields is too low. It has been projected that a large proportion of employment opportunities in the next century will be based on science and technology. To be adequately prepared for this reality it is critical for all our students to receive a strong science foundation. Many students are opting out of the sciences, and the majority of these are female.

IMPLICATIONS FOR EDUCATORS

As educators we need to become aware of prevailing social and cultural influences that may be having a negative effect on our students and work toward overcoming them. By positively incorporating knowledge gained from research into classroom practice, we can encourage more girls and boys to pursue the sciences. It is our responsibility to ensure that the doors are fully open to students with the ability and the desire to continue studying science. The following section provides guidelines to teachers in directing their pedagogy toward this end.

THE SUGGESTED APPROACH

Although the research from which the following points were extracted emphasizes techniques for encouraging girls in the sciences, all students can benefit from the practice of these recommendations.

Explain the reasoning behind answers to science and math problems and demand less conformity in the students' responses.

Having students rationalize their answers, whether right or wrong, reduces the inclination to merely memorize a response.

Structure learning in such a way that students perceive the logic behind the right answer. Having students rationalize their answers, whether right or wrong, reduces the inclination to merely memorize a response. This helps minimize the impression girls often have that they lack the talent for math and science, and reduces the socialization effect that causes girls to value pleasing the teacher over understanding the concept (Ridley and Novak 1983; Skolnick, Langbort and Day 1982; Steinkamp 1984).

Students can be required to include estimations when working with measurement. This enables them to envision the distance, volume or the mass, before going through the measuring steps. It encourages them to stop and "think" about what they are doing, rather than merely going through the motions.

Encourage girls to attribute success to ability and failure to lack of effort, rather than poor ability.

Fennema (1983) discovered that the confidence of girls when doing math was highly related to achievement. Similar parallels have been drawn for science (DeBoer 1984; Ridley and Novak 1983; Post-Kammer and Smith 1980). Girls often attribute their success to factors such as luck, other than their own ability, much more often than do boys (Fennema 1983; Hart Reyes and Padilla 1985; Skolnick, Langbort and Day 1982). In field studies by Dweck (1978), as cited in Skolnick, Langbort and Day (1982), teachers frequently reprimanded boys for not trying — giving males the impression that they don't succeed due to lack of effort rather than lack of ability.

The impressive impact of attributions for success is described in research by DeBoer (1984) with college students, in which he states, "... for successful students ... the plan to continue in science was directly related to their attribution of ability" (p. 328). Provide successful experiences that are the result of thinking through problems step by step. Different strategies used by students to approach a problem can be discussed and praised.

Provide successful experiences that are the result of thinking through problems step by step.

Distribute interactions evenly between boys and girls.

Research across the grades suggests that teachers spend more time interacting with male students than with female students (Fennema 1983; Fennema and Peterson, 1986; Hart Reyes and Padilla, 1985; Houston, 1985; Matyas, 1985; Morgan, 1985; Sadker and Sadker, 1985; Science Council of Canada, 1984; Skolnick, Langbort and Day, 1982).

Teachers can make a conscious effort to note the gender of students who tend to lead, as well as interrupt, class discussions, to ensure girls have an equal opportunity to participate.

Minimize sex-role stereotypes.

As teachers we can monitor our covert messages and not unthinkingly cause our students to limit their choices. Jokes and innuendoes implying the inadequacy of women in science should be eliminated from everyday conversation. Develop the habit of using his/her pronouns. Draw the class' attention to the contribution to society made by successful women in science. In textbooks, examples of gender bias can be pointed out to students and offset by displaying magazine and newspaper clippings of women in the sciences (Shapiro, Kramer and Hunerberg, 1981).

As teachers we can monitor our covert messages and not unthinkingly cause our students to limit their choices.

Use role models.

Teachers are influential role models as they spend a great portion of each day in contact with their students. Matyas (1985) found that the encouragement of a single high school teacher was often the deciding factor in the choice of a career in science.

Invite female guest speakers into the classroom on occasion — scientists, doctors, dentists engineers — from professions that still carry the male stereotype (Glaze, 1980; Kahle, 1985; Lowry and Woodhull, 1983; Rakow, 1984; Shapiro, Kramer and Hunerberg, 1981; Wells, 1985). A list of career women willing to visit classrooms in Alberta can be obtained through the "Stepping Stones Role Model Program", developed in 1989 by the Alberta Women's Secretariat, Alberta Career Development and Employment, and Alberta Education (for contact address see notation at the end).

Help girls to participate actively in math and science activities.

Be certain that girls as well as boys have an opportunity to help set up and operate classroom demonstration equipment.

Maximize the "hands-on" opportunities in the science classroom. In mixed-sex lab pairs have the students take turns recording and manipulating the apparatus. By insisting on such job rotations, we can avoid the common situation where males do most of the manipulation of materials and the girls are left to record the data (Science Council of Canada, 1984). The improvement of spatial perception skills in girls and written skills in boys is a spinoff from such activities (Baker, 1985; Higham and Navarre, 1984).

Be certain that girls as well as boys have an opportunity to help set up and operate classroom demonstration equipment. Developing such competency with equipment helps develop confidence about using technology (Shapiro, Kramer and Hunerberg, 1981).

Another technique designed to provide equity is to balance experimentation with discussions (Erickson and Erickson, 1984; Shapiro, Kramer and Hunerberg, 1981). Discussion, a verbal activity, boosts girls' self-confidence; while participating in science activities with spatial emphasis is an ego-booster for boys. The lesson, then, should incorporate activities and discussions to benefit both sexes.

Emphasize the link between science and society; include animate aspects when possible.

Girls become more interested in a subject when it is made relevant to life (Brady and Slesnick, 1985; Harding, 1982; Hart Reyes and Padilla, 1985; Kahle, 1985; Kremer, 1984; Simpson and Oliver, 1985). This supports observations made by Gilligan (1982) that led her to conclude that women "see a world comprised of relationships rather than of people standing alone; a world that coheres through human connection rather than through systems of rules . . . "(p. 29).

Examples should be drawn from the experiences of both girls and boys.

Regardless of whether physical, chemical or biological principles are being taught, capitalize on the animate aspects of science — relate examples to nature and the human body. Working with junior high science students, Simpson and Oliver (1985) found that the attitude of Grade 7 Life Science students of both sexes was more positive than the attitude toward science when the same students were taught Grade 8 Earth Science and Grade 9 Physical Science.

Examples should be drawn from the experiences of both girls and boys. In an electricity unit, for example, repairing a hair dryer or a curling iron could be included as easily as repairing a racing car set. This must be done without sex stereotyping, however. The idea is to spark the interest of both sexes by introducing items they have experienced. The students should be encouraged, however, to explore all items (Erickson and Erickson, 1984).

The Science Council of Canada in its report (1984) recommended a 50% science, technology and society (STS) emphasis in the science curriculum. The STS connection in the new science curriculum for Alberta provides opportunities for pointing out the relevancy of science to students' lives.

Balance cooperative with competitive activities and encourage autonomy in students.

Generally, boys respond better in competitive situations, while girls are more successful in classes that promote cooperative ventures (Fennema and Peterson, 1986; Lowry and Woodhull 1983; Maehr, 1983; Skolnick, Langbort and Day, 1982). By providing equal time for competitive and cooperative activities in the classroom we can capitalize on the strengths of both sexes.

By providing equal time for competitive and cooperative activities in the classroom we can capitalize on the strengths of both sexes.

Fenema and Peterson, in 1986, discovered that "in (Math) classes where girls learned more than boys, they were working more independently." Teachers can encourage students to solve problems on their own, rather than intervene too quickly.

Build successful experiences into science learning.

The key here is to build confidence. An emphasis on spatial skills causes girls very early to lose their confidence in doing science, and as a result they are less likely to take risks (Post-Kammer and Smith, 1985; Skolnick, Langbort and Day, 1982). Allowing many approaches, many right answers; playing question–asking games, where students ask questions rather than supply answers; encouraging guessing and estimating — all help to reduce the fear of taking risks.

Experiencing success is a great motivator for all students. Design activities so that success can be achieved readily. Breaking down assignments and experiments into steps makes them more accessible. Help students to realize that failure is a common occurrence in scientific endeavours.

Encourage girls to participate in extra-curricular science activities.

Clubs that have predominantly male membership, such as computer graphics or astronomy, can be sex-segregated initially, with a separate girls' and boys' time, and then integrated later. Girls can be encouraged to enter science fairs by having older students speak to the class on projects they have completed.

Stress to students and their parents or guardians, the connection between a strong science education and career options.

Both boys and girls need to be made aware of the importance of math and science to a broad variety of jobs and careers, so they can make choices in the future that will provide them with the widest range of options possible.

Both boys and girls need to be made aware of the importance of math and science to a broad variety of jobs and careers, so they can make choices in the future that will provide them with the widest range of options possible (Fennema, 1983; Hart Reyes and Padilla, 1985; Kahle, 1985; McNeill Kavrell and Petersen 1984; Post-Kammer and Smith, 1985; Steinkamp, 1984; Zerega and Walberg, 1984). In a study by Glaze (1980) of career aspirations and expectations of high school girls, over one-half of the girls stated they didn't know about the occupations available to enable them to make a well-informed career choice. To avoid the firm establishment of stereotypes, it has been recommended that occupational portrayal begin as early as age six (Marland, 1983).

Enthusiastically discussing the relevance of science to students' futures may encourage many of them to consider a career in the sciences.

CONCLUDING REMARKS

Educators have a role to play in combatting attitudes that prevent individuals from reaching their full potential because of gender. Not everyone will choose to pursue a science career but all will be affected by the new technology that inevitably emerges from scientific research. If society is to make wise decisions in the application of science, it is critical to encourage our students to become scientifically literate. To deny such input to any sector of society is a waste of intellect for which we could conceivably pay a high price. The adoption of a gender-sensitive approach to instruction will help to move science education in a positive direction.

The address for the "Stepping Stones" Role Model Program and registry is:

Janice White
Provincial Stepping Stones Coordinator
Alberta Women's Secretariat
8th Flr. Kensington Place
10011 – 109 Street
Edmonton, Alberta
T5J 3S8
Telephone: 422-4927

BIBLIOGRAPHY

Baker, D.R. 1985. "Predictive Value of Attitude, Cognitive Ability and Personality to Science Achievement in the Middle School." *Journal of Research In Science Teaching* 22: 103–113.

Brady, H., and T. Slesnick. 1985. "Girls Don't Like Fluffware Either." *Classroom Computer Learning.* April/May: 23–27.

DeBoer, G.E. 1984. "Factors Related to the Decision of Men and Women to Continue Taking Science Courses in College." *Journal of Research in Science Teaching* 21: 325–329.

DeBoer, G.E. 1986. "Perceived Science Ability and Effort Among Males and Females: Relationship to Persistence in Undergraduate Science Studies." Paper presented at the Annual Meeting of the American Educational Research Association, San Francisco.

Delamont, S. 1980. "Sex Roles and the School." In J. Eggleston (ed.). *Contemporary Sociology of the School.* New York: Methuen.

Erickson, G.L., and L.J. Erickson. 1984. "Females and Science Achievement: Evidence, Explanations and Implications." *Science Education* 68 (2): 63–89.

Fennema, E., and J. Sherman. 1977. "Sex-related Differences in Mathematics Achievement, Spatial Visualization and Affective Factors." *American Educational Research Journal* 4: 51–71.

Fennema, E. 1983. "Success in Mathematics." In M. Marland (ed.) *Sex Differentiation and Schooling* (p.163–180). London: Heinemann Educational Books.

Fennema, E., and P. Peterson. 1986. "Autonomous Learning Behaviors and Classroom Environments." Paper presented at the Annual Meeting of the American Educational Research Association, San Francisco.

Glaze, A. 1980. "Ontario Girls' Career Aspirations and Expectations." *Orbit* 11(3): 19–22.

Harding, J. 1982. "Notes and Correspondence: Girls and Science and Technology (GASAT)." *The School Science Review* 63: 570–571

Hart Reyes, L.H., and M.J. Padilla. 1985. "Science, Math and Gender." *The Science Teacher* 52(6): 43–48.

Higham, S.F., and J. Navarre. 1984. "Gifted Adolescent Females Require Differential Treatment." *Journal for the Education of the Gifted* 8: 43–58.

Houston, B. 1985. "Gender Freedom and the Subtleties of Sexist Education." *Educational Theory* 35: 359–369.

Kahle, J.B. 1985a. "A View and a Vision: Women in Science Today and Tomorrow. In J.B. Kahle (ed.). *Women in Science* (p.192–229). London: The Falmer Press.

Kahle, J.B. 1985b. "Retention of Girls in Science: Case Studies of Secondary Teachers." In J.B. Kahle (ed.). *Women in Science* (p. 49–76). London: The Falmer Press.

Kremer, B.K. 1984. "The Meta-analysis of Gender Differences in Science Learning: A First Step Toward the Develpment of Educational Policy to Encourage Women in Science." In M.W. Steinkamp and M.L. Maehr (eds.) *Advances in Motivation and Achievement Vol. 2. Women in Science* (p. 51–91). Greenwich, CT: JAI Press.

Lowry, N., and A. Woodhull. 1983. "Science for Women, Too: New Directions in Science Education." *Science for the People* 15 (1): 31–36.

Maehr, M.L. 1983. "On Doing Well in Science: Why Johnny No Longer Excels; Why Sarah Never Did." In S.G. Paris, G.M. Olson, and H.W. Stevenson. (eds.). *Learning and Motivation in the Classroom* (p. 179–210). Lawrence Erlbaum Assoc.

Marland, M. 1983a. "Guidance and Pastoral Care." In M. Marland (ed.). *Sex Differentiation and Schooling* (p.117–122). London: Heinemann Educational Books.

Matyas, M.L. 1985. "Factors Affecting Female Achievement and Interest in Science and in Scientific Careers." In J.B. Kahle (ed.). *Women in Science* (p. 27–48). London: The Falmer Press.

McNeill Kavrell, S., and A. Petersen. 1984. "Patterns of Achievement in Early Adolescence." In M.W. Steinkamp and M.L. Maehr (eds.). *Advances in Motivation and Achievement Vol. 2. Women in Science* (p. 1–35). Greenwich, CT: JAI Press.

Morgan, K.P. 1985. "Freeing the Children: The Abolition of Gender." *Educational Theory* 35: 351–357.

Post-Kammer, P., and P.L. Smith. 1985. "Sex Differences in Career Self-efficiency, Consideration and Interests of Eighth and Ninth Graders." *Journal of Counseling Psychology* 32: 551–559.

Rakow, S.J. 1984. "What's Happening in Elementary Science: A National Assessment." *Science and Children* 22(2): 39–40.

Ridley, D.R., and J.D. Novak. 1983. "Sex-related Differences in High School Science and Mathematics Enrolments: Do They Give Males a Critical Headstart Toward Science- and Math-related Careers?" *The Alberta Journal of Educational Research* 29: 308–318.

Sadker, M., and D. Sadker. 1985. "Sexism in the Classroom of the '80's." *Psychology Today* March: 54–57.

Science Council of Canada. April, 1984. *Science for Every Student: Educating Canadians for Tomorrow's World.* Report 36. Hull, Que: Canadian Government Publishing Centre. (Available from Canadian Government Publishing Centre, Supply and Services Canada, Hull, Quebec, K1A OS9, $5.25).

Shapiro, J., Kramer, S., and C. Hunerberg. 1981. *Equal Their Chances: Children's Activities for Non-sexist Learning.* New Jersey: Prentice Hall.

Simpson, R.D., and J.S. Oliver. "Attitude Toward Science and Achievement Motivation Profiles of Male and Female Science Students in Grades Six Through Ten." *Science Education* 69: 511–526

Skolnick, J., Langbort, C., and L. Day. 1982. *How to Encourage Girls in Math and Science.* Englewood Cliffs, NJ: Prentice Hall.

Steinkamp, M.W. 1984. "Motivational Style as a Mediator of Adult Achievement in Science." In M.W. Steinkamp and M.L. Maehr (eds.). *Advances in Motivation and Achievement Vol. 2. Women in Science* (p. 281–316). Greenwich, CT: JAI Press.

Steinkamp, M.W., and M.L. Maehr. 1983. "Affect, Ability and Science Achievement: A Quantitative Synthesis of Correlational Research." *Review of Educational Research* 53: 369–396.

Wells, M.R. 1985. "Gifted Females: An Overview for Parents, Teachers and Counselors. *G/C/T* 38: 43–46.

Zerega, M.E., and H. Walberg. 1984. "School Science and Femininity." In M.W. Steinkamp and M.L. Maehr (eds.). *Advances in Motivation and Achievement Vol. 2. Women in Science* (p. 37–50). Greenwich, CT: JAI Press.

"MICROCHEMISTRY" AND RESPONSIBLE DISPOSAL

by Margaret–Ann Armour, University of Alberta

The Minimization of Chemical Wastes From School LaboratoriesL: Microscale Experiments and Other Strategies

INTRODUCTION

The disposal of chemical waste is only one aspect of the larger area of chemical management. Another aspect which is increasingly being practised is the minimization of chemical waste.

The inappropriate disposal of hazardous waste and surplus chemicals can be a hazard both to human health and to the environment. As a result of the recognition of both moral and l legal obligations, the responsible disposal of waste chemicals from academic laboratories has received considerable attention from administrators, educators and waste disposal specialists. In Alberta, we are fortunate to have a Special Waste Treatment Facility to which wastes can be sent. However, the disposal of chemical waste is only one aspect of the larger area of chemical management. Another aspect which is increasingly being practised is the minimization of chemical waste. This article addresses strategies for reducing the volume of chemical waste which must be sent off-site for disposal. Firstly, the use of microscale experiments is discussed, and secondly, some practical laboratory methods for the reduction of specific chemical wastes are suggested.

Essential to the implementation of these strategies and to overall good chemical management, is the involvement of students, teachers and administrators. Thus, the sectionbegins by briefly suggesting ways of involving these groups, continues by describing minimization strategies including some technical information, then lists the experiments in Science 10, 20 and 30, Biology 20 and 30, Physics 20 and 30 and Chemistry 20 and 30 in which chemical wastes are likely to be generated and provides some specific suggestion of how the wastes from these experiments can be reduced, and lastly summarizes well-accepted practices for the final disposal of residual wastes. It is hoped that information will be applicable as the new science curriculum is introduced and will allow students, teachers and administrators to pull their efforts to reduce the production of hazardous chemical wastes in Alberta schools

COMMITMENT

Students

It is important to involve students in the actual chemical waste management program of their own school so that they become part of the planning and execution of the program.

Students are presently very committed to preserving the environment. This enthusiasm can be used to advantage in the management of laboratory wastes. Part of the training of students in any experimental science and especially in chemistry includes information on safe practices in the laboratory and on the handling of hazardous materials. In Unit 3 of Science 10, Unit 3 of Science 20 and Unit 2 of Science 30, students are formally introduced to the handling, storage and disposal of chemical wastes. As part of this unit, students will learn about some of the practical technique available for handling waste safely. However, it is also important to involve students in the actual chemical waste management program of their own school so that they become part of the planning and execution of the program. In this way, they recognize the commitment of their teachers and the school to responsible handling of hazardous chemical waste. Further, the awareness of those students who have not thought about the issue is raised. Students can learn how some hazardous chemicals can be treated at the laboratory bench to yield non-hazardous materials and these reactions can be incorporated into a laboratory exercise, teaching both a chemical principle and a practical method of waste disposal. Some examples of disposal experiments are included later in this document.

Teachers

Dramatically reducing the scale of at least some of the experiments performed in the laboratory has many positive results.

Teachers have several responsibilities in the management of wastes. It is obvious that the ideal is to reduce the waste to the least possible quantity. This can be accomplished in several ways. A method which has become much used is that of reducing the scale of experiments. This has proved to have interesting results. Not only does it increase the safety of the experiment since the quantities of chemicals being used are much less, it also results in much smaller quantities of waste products. Interestingly, in addition it has been found that there is an increased enthusiasm by students for performing experiments on a small scale. Whether this is due to an intrinsic pedagogical interest of small-scale experiments and/or to an increased involvement of the teacher in these new techniques, it is not yet easy to tell. Whatever the reason, dramatically reducing the scale of at least some of the experiments performed in the laboratory has many positive results. Secondly, the design of experiments on whatever scale can be such that the generation of waste is considered and its minimization given high priority. In some instances, it is possible to use the product of one experiment as the starting material of another. In other cases, the manner of distribution of chemicals to the student can be accomplished in such a way that waste is reduced. In yet other cases, the products of an experiment or surplus material can be treated and reused. Where it is not practical to further reduce the formation of waste, it may be possible to treat at least some of the remainder on site, to convert it to non-toxic chemicals which are readily disposed of, or at least to reduce the volume of the material which must be sent off-site for disposal.

Administrators

As in any organization, there has to be a commitment on the part of the school administration to minimize waste and to provide teachers with both the incentive and the means to accomplish this goal. Thus, consultants, especially science consultants, need to become knowledgeable about practical ways of reducing waste and be prepared to communicate these to the laboratory teacher. School principals have to support and encourage the efforts of the teachers and the students.

STRATEGIES FOR WASTE MINIMIZATION

Microscale Experiments

It has been traditional in school laboratories for students to perform experiments using gram quantities of chemical. Several years ago, in response to safety concerns about the exposure of students to laboratory chemicals and the increasing cost of disposal of waste and surplus materials, Mayo and Pike pioneered the use of small quantities of starting materials in university chemistry laboratory experiments. They developed the so-called microscale experiments. Their criterion was that none of the starting chemicals used should be in a quantity greater that 100 milligrams, i.e., 0.1 gram. In the short time since microscale experiments were introduced, they have become increasingly popular and have made their way into the classrooms of secondary schools as well as post-secondary institutions. Just as a recipe for cookies can be reduced if desired, chemical experiments are often equally successful using considerably smaller quantities of starting materials. As has been mentioned, students also seem to enjoy performing experiments on a miniature scale. When students are planning experiments to investigate a particular concept, they should be encouraged to think about using a small scale. When experiments are being performed which are detailed in

Just as a recipe for cookies can be reduced if desired, chemical experiments are often equally successful using considerably smaller quantities of starting materials.

support material, quantities can often be halved or even further reduced. Although not strictly 'microscale' as defined by Mayo and Pike, experiments using quantities of starting materials between 0.1 and 1 gram are often very practical. This may require the use of different or suitably adapted glassware and equipment. Instead of using beakers and Erlenmeyer flasks, many experiments on a microscale can be performed in small test tubes. Disposable or Pasteur pipettes calibrated to allow delivery of 0.5 mL or 1mL can be used. Qualitative analysis of inorganic ions can be performed on reaction plates which have a series of wells in which tests on very small volumes of liquid can be performed. Disposable pipettes in which the stem has been cut short and small wad of glass wool inserted can be substituted for filter funnels to collect a few crystals by filtration.

Methods for Laboratory Reduction and Disposal of Chemical Waste

There are many straightforward and practical ways of reducing the chemical waste which has to be sent off site for disposal. Some of these ways which may be applicable in the school laboratory are described here. However, it is important to remember that the disposal must comply with the Hazardous Waste Regulation of the Alberta Hazardous Chemicals Act. Further, appropriate personal protective equipment including eye protection, gloves and laboratory coat should be worn by anyone performing the reactions. As far as possible, and in all cases where noted, the manipulations should be performed in an effective fume hood.

Neutralization of Acids and Bases

Waste quantities of acids such as hydrochloric acid, sulfuric acid, nitric acid and acetic acid, and bases such as sodium and potassium hydroxides can be neutralized and washed into the drain. Concentrated acids and bases are first added to 20 times their volume of water so that their concentration is below 5%. *Caution: Never add waster to concentrated acid.* To the dilute acid solutions, are slowly and carefully added dilute solutions of waste base or 5% sodium hydroxide solution of solid sodium carbonate (soda ash) until the pH is between 6 and 8. Waste dilute solutions of base can be treated with waste dilute solutions of acid or with 5% hydrochloric acid solutions. The neutralized solutions can be washed into the drain.

Distillation of Used Solvents

Organic solvents such as methanol, ethanol and petroleum ether used in a reaction or as a solvent in chromatography can often be recovered for reuse by distillation. If possible the distillation apparatus should be set up in a fume hood. The flask should be heated using a water bath (for low boiling solvents such as methanol and petroleum ether), oil bath or heating mantle. The contents of the distilling flask should never be allowed to evaporate to dryness.

Evaporation of Aqueous Solutions

The volume of dilute aqueous solutions of toxic materials can be greatly reduced by allowing the solution to evaporate in a fume hood or other well-ventilated area. Such solutions might contain salts of heavy metals. They should be poured into a wide-mouthed container such as an evaporating basin or large beaker and allowed to stand at room temperature until most of the water has evaporated and only a sludge remains. This sludge should be transferred to an appropriate labelled container for off-site disposal.

Precipitation of Heavy Metal Salts

An alternative to allowing dilute aqueous solutions of heavy metal salts to evaporate to yield a small quantity of sludge is to precipitate the metals as an insoluble salt which can be removed by filtration or by allowing the solid to settle and pouring of the liquid. Specific directions for precipitating lead ions from solution as their silicate is described as well as the modifications needed to use this method for other heavy metal ions.

$$Pb^{2+} \rightarrow Na_2SiO_3 \rightarrow PBSiO_3 + 2Na^+$$

To a solution of a soluble lead salt (0.01 mole, e.g. 2.75 g of lead chloride in 50 mL of water) is added a solution of sodium metasilicate (waterglass, $Na_2SiO_3 \cdot 9H_2O$, 8.5 g, 0.03 mole) in water (50 mL) with stirring. The pH is adjusted to about 7 by the addition of 2*M* aqueous sulfuric acid (approximately 15 mL will be needed). The precipitate is collected by filtration, or the mixture allowed to stand until the solid has settled to the bottom of the container and the liquid can be poured off. The solid is allowed to dry, packaged and labelled for disposal.

For dilute solutions of lead salts of unknown concentration the sodium metasilicate solution should be added until there is not further precipitation, the pH is adjusted to 7-8 by the addition of 2 *M* sulfuric acid, and the solution allowed to stand overnight before collecting the solid by filtration or allowing it to settle and pouring off the liquid. Solutions of cadmium and antimony salts can be treated similarly.

Several other heavy metal salts can also be precipitated as the silicates. The quantities given for lead are also appropriate for 0.01 moles of these metals. The only modification necessary is a change in the pH at which the silicate is precipitated. They include iron (II) at pH 12, iron (III) at pH 11, Zn (II) at pH 7–7–.5 and Al (III) at pH 7.5–8. Cu (II), Ni (II), Mn (II) and Co (II) can be precipitated without adjustment of the pH from that after the addition of the solutions of sodium metasilicate. Similarly, solutions of unknown concentration can be treated with sodium metasilicate solution until there is no further precipitation, the pH adjusted to the required value by the addition of 2 *m* sulfuric acid of 5% sodium hydroxide solution and the mixture allowed to stand overnight before collecting the solid by filtration or allowing it to settle and pouring off the liquid. After standing in the air to dry, the metal silicates should be placed in a labelled container for disposal. The liquids can be washed into the drain.

<u>Oxidizing Agents</u>

Solutions of compounds such as potassium permanganate, sodium chlorate, sodium periodate and sodium persulfate should be reduced before being discarded into the drain to avoid uncontrolled reactions in the sewer system. The reduction can be accomplished by treatment with a freshly prepared 10% aqueous solution of sodium bisulfite or metabisulfite. Precise quantities and conditions for these reactions are detailed in the table below

Oxidizing Agent Present in Waste Stream	Quantity and Concentration of Oxidizing Agent in Aqueous Solution	Quantity of 10% Aqueous Sodium Metabisulfite	Comments
Potassium Permanganate	1 L of 6%	1.3L	Solution becomes colourless
Sodium Chlorate	1 L of 10%	1.8 L	50% excess reducing agent added
Sodium Periodate	1 L of 9.5%	1.7 L	Solution becomes pale yellow
Sodium Persulfate	1 L of 10%	0.5 L	10% excess reducing agent added

Treatment of Formalin (Formaldehyde Solution)

$HCHO + ClO^{+} \rightarrow HCOOH + Cl^{+}$

formalin solution — formic acid

In the fume hood, the formalin solution is diluted with 10 times its volume of water. The dilute solution is added slowly and with stirring to an excess of household bleach (25 mL for each 10 mL of the diluted formalin solution). The mixture is allowed to stand at room temperature overnight and then washed into the drain.

Treatment of Iodine and Iodine Solutions

$I_2 + Na_2S_2O_3 + Na_2CO_3 \rightarrow 2NaI + Na_2SO_4 + S + CO_2$

Solid iodine

In the fume hood, the solid iodine (1 g) is cautiously added to a solution of sodium thiosulfate (2.5 g in 60 mL of water) containing sodium carbonate (0.1 g). The mixture is stirred until the iodine has all dissolved and the solution is colourless, then solid sodium carbonate is added if needed to bring the pH of the solution to between 6 and 8. The solution is washed into the drain.

Solutions of iodine

Sodium thiosulfate solution (4 g in 100 mL of water) containing sodium carbonate (0.1 g) is added to he iodine solution, with stirring, until the solution becomes colourless. Sodium carbonate is added if necessary to bring the pH of the solution to between 6 and 8 the liquid is washed into the drain

Other Miscellaneous Strategies for Minimizing Chemical Waste

Buying Chemicals in Bulk – A False Economy

Suppliers sometimes sell large quantities of chemicals at considerable savings. However, such purchases may be false economy. Several factors must be considered before making such a purchase. For example, how long will the large quantity of chemical last with normal use and will it decompose under the storage conditions in the school during this time? Many chemicals have limited shelf lives and, in addition to being no longer acceptable in the experiment for which they were bought, they may even become hazardous. Adequate storage space and facilities

How long will the large quantity of chemical last with normal use and will it decompose under the storage conditions in the school during this time?

Is there likely to be a change in the curriculum so that the experiment for which the chemical is needed is no longer included?

may not be available in school. Another question must also be asked: is there likely to be a change in the curriculum so that the experiment for which the chemical is needed is no longer included? If the chemical is no longer needed and much of it has to be sent for disposal, the savings on its purchase will be lost and increased cost may even be incurred.

Dispensing Chemicals in the Laboratory to Reduce Waste

It is sometimes necessary to strike a balance between dispensing all chemicals in the quantities required by each individual student and teaching students to measure for themselves the amounts needed in the experiments. The decision whether to provide premeasured quantities will depend largely on the hazard associated with the chemical If it is a chemical which is non-toxic and non-hazardous, like sodium carbonate, then waste amounts generated as the students measure the quantity they require are easily disposed of; if, on the other hand, the chemical is magnesium ribbon, it would be preferable for the teacher to cut the appropriate length of ribbon for each student so that waste pieces do not result. Similarly, it is desirable to minimize both the waste and the possibility of spillage of solutions of lead salts, so that premeasurement may be desirable.

SUGGESTIONS FOR WASTE MINIMIZATION AND DISPOSAL

Experiments in Science 10

Unit 2. Matter and Energy in Living Systems

Staining plant and animal material for observation
If solutions of dyes are required for staining, prepare least possible volume to minimize waste

Action of starch and sugar solutions in dialysis bags
If iodine solution is used to detect starch, dispose of excess iodine solution with sodium thiosulfate as described in the previous section

Unit 3: Matter and Energy in Chemical Change

Using common separation techniques, such as filtration, extraction, distillation and chromatography
Microscale; collect and recover any solvents used in chromatography by distillation

Investigation of the properties of some ionic and molecular compounds including acids and bases
Microscale; precipitation of ions from solution; evaporation of aqueous solutions; neutralization of acids and bases

Handling and disposal of chemicals in a safe, responsible manner
Inclusion of experiment involving reuse and disposal of waste or surplus chemical, e.g., distillation of solvents from chromatography for reuse and conversion of the iodine solution used in Unit 2 to non-toxic sodium iodide

Combustion experiments
Microscale

Unit 4: Energy and Change

The investigation of energy conversions
Microscale for any chemical energy investigations

Experiments in Science 20–30

Science 20, Unit 1: The Changing Earth

Identifying common rock types
Microscale for any chemical tests on the rock

Science 20, Unit 2: Changes in the Living Systems

Measurement of pH, temperature, hardness and oxygen content in the freshwater ecosystem
Microscale where chemical tests used; disposal of acids and bases by neutralization; evaporation of aqueous solutions

Science 20, Unit 3: Chemical Changes

Disposal of used laboratory chemicals using safe and accepted procedures
Dispose of waste chemical using one of the methods described in the previous section

Investigation of the properties of solutions
Microscale; where appropriate, precipitate heavy metals from solution as insoluble silicates; evaporate dilute aqueous solutions

Determination of the identity of common ions
Microscale; precipitate heavy metals from solution as insoluble silicates; evaporate dilute aqueous solutions

Constructing electrolytic and galvanic cells
Precipitate heavy metals from solution as insoluble silicates; silver ions can be recovered from solution as sliver nitrate

Investigation of the properties of hydrocarbons and other organic compounds
Microscale; recover for reuse; if necessary, purify hydrocarbons and other lower boiling organic compounds by distillation

Science 30, Unit 1: Living Systems Respond to their Environment

Observing, drawing and labelling a dissected mammalian heart, eye, brain
If formalin is used as perserving solvent, oxidize using bleach; if other preserving solvent is used, recover by distillation

Preparing tissue for microscopic observation
Disposal of surplus stain solution

Science 30, Unit 2: Chemistry in the Environment

Testing samples of air and water
Microscale

Disposal of used laboratory chemicals
Use of procedure described in previous section

Use of diagnostic tests to differentiate among acids, bases, and neutral compounds and between strong and weak acids and bases, titration experiment to determine the concentration of an acid or base solution
Microscale; neutralization of acids or bases; reduction of oxidizing ions; evaporation of dilute aqueous solutions

Investigation of the properties of alcohols, aldehydes, ketones, organic acids, amines and esters
Microscale

Preparation of a synthetic polymer
Microscale; recovery of solvents used and purification for reuse by distillation

Experiments in Biology 20–30

Biology 20, Unit 1: The Biosphere

Performing an experiment to demonstrate solar energy storage by plants
If iodine solution is used as a starch indicator, dispose of surplus solution using sodium thiosulfate

Biology 20, Unit 2: Cellular Matter and Energy Flows

Using chromatography techniques to separate pigments from plant leaves
Recovery of chromatography solvent for reuse by distillation

Demonstration that plat leaves produce starch
If iodine solution is used as a starch indicator, dispose of surplus solution using sodium thiosulfate

Biology 20, Unit 3: Matter and Energy Exchange in Ecosystems

Measurement of temperature, precipitation, pH, hardness and oxygen content in aquatic and terrestrial ecosystems
Microscale where chemical tests used; disposal of acids and bases by neutralization; evaporation of aqueous solution

Biology 20, Unit 4: Matter and Energy Exchange by the Human Organism

Qualitative analysis to detect the presence of carbohydrates, lipids and proteins in food
Microscale; evaporation of waste aqueous solutions of reagents

Biology 30, Unit 1: Systems Regulating Change in Human Organisms

Investigation of the presence of reducing sugars in (simulated) urine
Microscale; if Fehling's solutions used to detect the present of reducing sugars, precipitate the copper from waste or surplus solutions as the silicate

Experiments in Physics 20–30

Physics 20, Unit 4: Light

Determining the index of refraction of several different substances
If liquids used, recover for reuse, distill if necessary; if solutions used, allow to evaporate

Experiments in Chemistry 20–30

Chemistry 20, Unit 1: Matter as Solutions, Acids, Bases and Gases

Identification of solutions using a simple conductivity apparatus
Precipitation of heavy metal ions as silicates; evaporation of aqueous solutions

Preparation of solutions of specified concentration, identification of an ion
Microscale

Differentiating among acidic, basic and neutral solutions using indicators, pH and conductivity
Microscale; neutralization of acids and bases for disposal

Chemistry 20, Unit 3: Chemical Bonding in Matter

Investigation of the reactivity of various metals with oxygen and dilute acids
Microscale; precipitation of heavy metal ions as silicates; evaporation of aqueous solutions; neutralization of acids before disposal

Chemistry 20, Unit 4: The Diversity of Matter: An Introduction to Organic Chemistry

Investigation of the physical and chemical properties of some organic compounds
Microscale; small volumes of volatile organic liquids can be allowed to evaporate in the fume hood

Synthesis of an organic compound
Microscale; if volume warrants, distill solvents recovered in the experiment for reuse

Chemistry 30, Unit 1: Thermochemical Changes

Investigation of molar enthalpies of physical and chemical changes
Reduce scale of experiments as far as possible

Chemistry 30, Unit 2: Electrochemical Changes

Experiments for deriving a simple reduction table, testing predictions about oxidation-reduction reactions, determining concentration of unknown by oxidation-reduction titrations
Microscale; precipitate heavy metal ions form solution as silicates; allow aqueous solutions to evaporate

Construction of electrolytic and electrochemcial cells

Chemistry 30, Unit 3: Equilibrium, Acids and Bases in Chemical Changes

Testing predictions of equilibrium shifts, performing and experiment to differentiate among strong and weak acids and bases and other solutions
Microscale; dilute and neutralize acids and bases before disposal

Comparison of the reactivity of inorganic and organic acids and bases
Microscale; dilute and neutralize acids and bases before disposal

Standardization of an acid or base solution, using indicators to determine the pH of an acid or base solution and testing buffer action
Reduce scale of experiments as much as practical; dilute and neutralize acid and base before disposal

THE HANDLING OF RESIDUAL CHEMICAL WASTE

After all the strategies have been used to reduce, as far as possible, the quantity of residual chemical waste, there are certain practices which should be followed to dispose of the remaining waste safely. These are described in the booklet *Guidelines for Management of Chemical and Hazardous Wastes in Schools* produced by Alberta Education and the Alberta Special Waste Management Corporation. Only the in-laboratory practices for collecting, labelling and storing the wastes before placing them in labpacks for disposal and preparing manifests are summarized here.

Identification and Labelling

When several different chemical wastes are generated in a laboratory experiment, as far as possible they should be placed in separate clearly labelled containers instead of being mixed together. It may be possible to have these containers in the laboratory so that the students can put their waste directly into the appropriate container. With clear instructions and careful monitoring, this can be successful. Where the waste consists of more than one chemical, both must be identified on the container. For example, if the waste is a solution of an organic compound in a solvent, both must

The waste container should be labelled with the full chemical name of the waste, or if it is mixed waste, with the names of all the chemicals present in the waste, the approximate volume and the date generated.

be identified. The waste container should be labelled with the full chemical name of the waste, or if it is mixed waste, with the names of all the chemicals present in the waste, the approximate volume and the date generated. This makes it easier to comply with the documentation requirements before the waste can be transported for disposal.

Storage

Obviously, waste should be stored for as short a time as possible. However, waste is unusually only collected when there is sufficient to fill one or more labpacks, so it may be necessary to store it, especially where only small quantities of waste are generated. The waste should be stored in a secure and well-ventilated area, using guidelines similar to those for the storage of laboratory chemicals. In addition to showing the identity of the water, the labels on the containers should also clearly indicate that the material is waste waiting for disposal.

Record Keeping

It is essential to keep an inventory of the chemical waste. this should include information present on the label of the waste container, i.e., name or names of chemicals in the waste, approximate volume of the waste, the date of its generation and its storage location.

REFERENCES

Alberta Education and Alberta Special Waste Management. 1991. Guidelines for Management of Chemicals and Hazardous Waste in Schools, Edmonton, AB.

Armour, M.A., Browne, L.M., and G.L. Weir. 1986. *Hazardous Chemicals Information and Disposal Guide.* Edmonton, AB: available from Department of Chemistry, University of Alberta.

Bretherick, L. 1990. *Handbook of Reactive Chemical Hazards*. 3rd edition. Toronto: Butterworth.

Kaufman, J.A., ed. 1988. Waste Disposal in Academic Institutions, Lewis Publishers Inc., Chelsea: MI

Mayo, D., Pike, R., and S. Butcher. *Microscale Organic Laboratory*, St. Catharine's, ON: Boreal Laboratories Ltd.

Merck and Co., Inc. Merck Index. 11th edition. Rahway NJ. 1989.

Pitt, M.J. and E. Pitt. 1986. *Handbook of Laboratory Waste Disposal.* Wiley, NY.

Russo, T. *Microchemistry Lab Manuals for High School General Chemistry Classes.* Boreal: St. Catharine's Laboratories Ltd.

SECTION 4: PREPARATION AND PLANNING

by Desiree Hackman

PLANNING FOR A STUDENT-CENTRED CURRICULUM

When planning for a student-centred curriculum it is helpful to identify the characteristics to be developed in the Science 10 student.

Characteristics of a Science 10 Student:

Concepts

- makes linkages among the sciences
- makes connections among scientific concepts, principles and themes

Skills

- scientific process
- technological problem solving
- decision making
- recognizes and applies skills to new situations
- communicates findings
- exhibits higher level thinking processes

Science 10 Student

(Active Learner)

STS Connections

- makes connections from scientific concepts and themes to happenings in daily life and community

Attitudes

- motivated learner
- self-directed learner
- finds science personally relevant
- prepared for further study and/or careers in science
- lifelong learner with a continuing interest in science

A significant paradigm shift is required on behalf of the teacher and student in order to be successful in developing these characteristics. The teacher must shift from an expert/lecturer to a facilitator of learning, and the student must shift from a reproductive thinker to an autonomous thinker.

PLANNING

Prior to formal planning it is strongly recommended that teachers read the Alberta Education background documents listed below as they provide a framework or mindset for planning.

Teaching Thinking: Enhancing Learning

Focus on Research

STS Science Education: Unifying the Goals of Science

Ordering information for these documents is found in the Resources section of this TRM.

Teaching Thinking: Enhancing Learning suggests an effective approach to teaching thinking, possible student activities, and suggestions for evaluating thinking.

Teaching of thinking skills is an integral part of the school curricula. Teachers intuitively teach thinking skills; however it is necessary to translate intuitive teaching into deliberate, planned instruction. *Teaching Thinking: Enhancing Learning* suggests an effective approach to teaching thinking, possible student activities, and suggestions for evaluating thinking.

Focus on Research describes a comprehensive, 5-stage research process.

In response to the information age, one of the most important skills a student can take into the "real world" is the ability to access, organize and use information. Research projects help students acquire these skills. *Focus on Research* describes a comprehensive, 5-stage research process. It also offers suggestions for planning, examples for implementing research, and sample evaluation techniques.

When planning a research project for students, ensure that information is "accessible " to the student. Teachers will find that working cooperatively with the library staff or with colleagues to find and research suitable topics will help achieve success through expansion of student research skills. Teachers and students may need to reach beyond traditional library resources to gather information. For example, a, phone call, letter or visit to a municipal, provincial or federal government office could provide information. Business, industry and non-government organizations may also provide additional resources or information.

The three STS learning contexts are the nature of science, science and technology, and science-related social issues.

The three STS learning contexts are the nature of science, science and technology, and science-related social issues. In planning for the new science courses, every lesson should have one or more of these contexts. For example, the primary focus of a lesson may be a social issue arising from a local newspaper article. The teacher and students can explore the principles and theories of science within the framework of the principles and theories of science within the framework of the learning context. It is important to choose issues of interest or concern to the student and to develop concepts from concrete to abstract. This method provides a motivating framework for students to learn the required concepts, skills and STS connections.

Language development is closely associated with development of thinking skills.

Language development is closely associated with development of thinking skills. Development of communication skills in the context of the science classroom is an important component of the new science programs. A wide range of written and oral assignments are to be provided to students and the communication component is to be evaluated along with the science in the assignment. Writing, speaking, viewing and listening skills are all to be used and planned into the lessons.

For additional information see Language for Thinking and Communication – Section 3F.

Once a mental framework has been established, the following resources are available to assist course, unit and daily lesson planning.

Checklist

- **Programs of Study**
- **Teacher Resource Manuals**
- **Basic Learning Resources**
- **Suport Learning Resources**
- **Authorized Teaching Resources**
- **Other Resources**

Programs of Study

The programs of study describe the rationale, philosophy, goals, general learner expectations and specific learner expectations associated with each course. There are no elective or optional units in the programs of study. Teachers are called upon to tailor the prescribed program to the nature and needs of the learner providing enrichment, extension and remediation activities where appropriate.

Science 10-20-30
Biology 20-30
Chemistry 20-30
Physics 20-30

Teacher Resource Manuals

Teacher resource manuals are support documents developed by Alberta Education. This TRM provides background for instruction/assessment/evaluation strategies. It also includes a resource list in Section 6. The list includes print and non-print resources **authorized** by Alberta Education: Basic Learning Resources, Support Learning Resources and Authorized Teaching Resources. The Other Resources list includes resources which are identified as useful for teachers in the implementation of the senior high science programs but which have not undergone formal review procedures in Alberta Education

The Science 10 and 20-level TRMs provide sample lesson plans for each of the units within the course and resource lists specific to each course.

Senior High Science TRM (interim)
Science 10 TRM (interim)
Science 20 TRM (field validation draft)
Biology 20 TRM (field validation draft)
Chemistry 20 TRM (field validation draft)
Physics 20 TRM (field validation draft)

Basic Learning Resources and Accompanying Teacher's Guides

Basic Learning resources are authorized by Alberta Education and are the resources most appropriate to support each course. The basic resources are stocked at the LRDC and qualify for a 25% basic learning resource acquisition subsidy by Alberta Education. Teacher guides often are available to offer support for the individual textbooks.

Science 10
Visions 1 – Gage Educational Publishers Ltd.
Science 20
Visions 2 – Gage Educational Publishers Ltd. – under development
Science 30
Visions 3 – Gage Educational Publishers Ltd. – under development

Biology 20-30
Biology Directions - John Wiley and Sons
Nelson Biology - Nelson Canada

Chemistry 20-30
Addison-Wesley Chemistry - Addison-Wesley
Nelson Chemistry- Nelson Canada

Physics 20-30

Fundamentals of Physics - D.C. Heath

Physics Principles and Problems - Maxwell, MacMillan

Support Learning Resources

Support learning resources are those student learning resources authorized by Alberta Education to assist in addressing some of the learner expectations of course(s) or components of course(s); or assist in meeting the learner expectations across two or more grade levels, subject areas, or programs as outlined in the provincial Programs of Study.

Authorized Teaching Resources

Authorized teaching resources are those teaching resources produced externally to Alberta Education for example, by publishers, that have been reviewed by Alberta Education, found to meet the criteria of review and to be the best available resources to support the implementation of Programs of Study and Courses, and the attainment of the goals of education; they have been authorized by the Minister. Teaching resources produced as service documents by Alberta Education, such as teacher resource manuals (TRMs), diagnostic programs and monographs, are authorized by definition.

Other Resources

Other learning resources are those learning resources identified by Alberta Education as useful for teachers in the implementation of a course(s) or Program(s) of Study, but which have not undergone review procedures in Alberta Education. Alberta Education does not accept responsibility for use of these resources with students. It is the responsibility of the teacher to determine the suitability and application of these resources.

COURSE PLANNING

Each course of study is designed for the teacher to progress from Unit 1 through Unit 4 (or 5). References to prior learning occur in the latter units and skill development builds from Unit 1 to Unit 4 (or 5). It is possible to reorder the units or teach completely around themes if teachers provide the necessary background, concept and skill development in their unit or lesson plans.

You may opt for a disciplines approach, an integrated approach or a unified approach to teaching the courses.

There are many different ways to approach course planning. Descriptions of three approaches are found in Section 3A of this TRM. You may opt for a disciplines approach, an integrated approach or a unified approach to teaching the courses. Regardless of the approach, planning must be carefully thought out to meet all of the requirements of the Course of Studies.

Note: The Science 10-20-30 program is designed to facilitate the integration of the disciplines. Teachers should model this interdisciplinary approach. It is not appropriate to have a different-discipline teacher teaching each of the four units of each course.

Using a calendar or sheet indicating dates and days, draw up a draft plan to indicate timelines for the unit, theme or topic.

The approach to teaching the course will determine the time allocated for each unit, topic or theme. Using a calendar or sheet indicating dates and days, draw up a draft plan to indicate timelines for the unit, theme or topic. Block off school days that will be lost due to statutory holidays or other predetermined events that you are aware of within your school. This allows for equitable distribution of the time available and will lead into the specific planning for each unit, such as establishing dates for field trips, guest speakers, library research, ordering and viewing of resources, equipment ordering and repair, chemical disposal and purchase, and unit quizzes and exams.

A master sheet for course planning by month has been included on page 7.

With a focus on student-centred learning, evaluation takes on a new meaning.

With a focus on student-centred learning, evaluation takes on a new meaning. Performance assessment, assessment of problem-solving skills, student self-assessment, and holistic scoring become important means of assessment and evaluation. Student portfolios, lab exams and research projects become important components for the evaluation of students. These alternative methods of evaluation require thought and planning.

Outlines distributed to students should include evaluation criteria so individual students can keep a record of their own progress.

Evaluation criteria should be drawn up before the course begins. A plan for marks distribution over the whole course, as well as for each unit, should be prepared and distributed to students, parents and administrators. Outlines distributed to students should include evaluation criteria so individual students can keep a record of their own progress. A sample course and unit Assessment and Evaluation plan can be found in Section 5 of this TRM.

MONTH: ____________ YEAR: ____________ CLASS: ____________

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY

275

NOTES:

Business, industry and other agencies/organizations have a strong interest in making a contribution to the education of students. Partnerships may take the form of a speaker visiting a class to discuss careers or background on specific topics, a tour of the workplace or facilities, or enlisting volunteers to judge science fairs or science olympics. Some jurisdictions have a coordinator to facilitate partnership initiatives. With funding and support from Science Alberta Foundation and Alberta Lotteries, Edmonton, Calgary and Medicine Hat have initiated "Science and Technology Hotlines". Teachers will be able to access information, resources, demonstrators, speakers, career counsellors and other services from a variety of scientific and technological areas. Possibilities are endless if you take the time to make a few inquiries and plan to integrate partnerships into your science programs.

Business, industry and other agencies/organizations have a strong interest in making a contribution to the education of students.

Increased demands placed on science facilities may require long-range planning for upgrading of equipment and facilities. One reference that will provide a framework from which to assess needs for future planning is the *Science Facilities for Secondary Schools in the 21st Century* document which was provided to all field test teachers and is available on request from the Curriculum Branch.

Increased demands placed on science facilities may require long-range planning for upgrading of equipment and facilities.

When planning any activities for the classroom, it is important to consider the safety of all individuals involved. WHMIS guidelines have been legislated to ensure the safety of students, employees and the environment in the handling of hazardous materials.

When planning any activities for the classroom, it is important to consider the safety of all individuals involved.

INTEGRATION OF COMPUTER TECHNOLOGY

Access to computer labs/software/simulations is often limited. It may be necessary to make arrangements to switch classrooms with the computing classes and make long range plans to gradually acquire computers for science classrooms

Encourage students to utilize computer technology through the use of word processing, data bases, spreadsheets or graphics, simulations, laboratory interfaces or bulletin board systems. Videodiscs and CD-ROM technology offer opportunity for research enrichment, extension or remediation activities. There are many ways to integrate computer technology in the science classroom.

For additional information see Technology and Media – Section 3N.

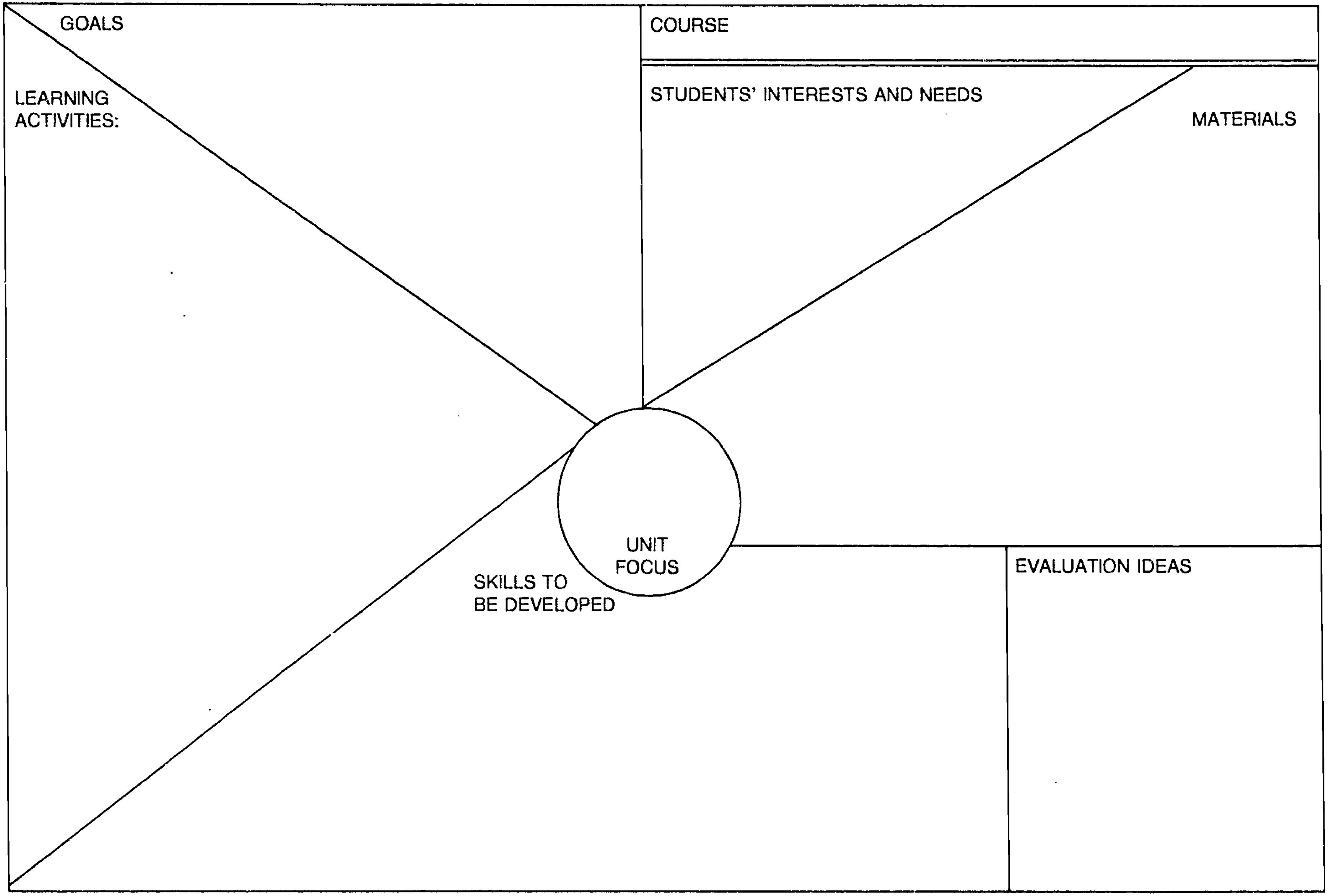
UNIT PLANNING

Unit planning is not a linear process. Teachers must consider student interests and needs, program goals, activity selection, materials, facilities, equipment and evaluation ideas when planning unit components. A unit pre-planning sheet modified from the Senior High English TRM is included on page 11 to assist with development of a unit plan.

If this is your first time teaching the course, be careful not to be too ambitious. There is a tendency to cover too much in order to prepare the student for the next course. Constantly refer to the Program of Studies to ensure that you are on track. Be realistic about what can be accomplished in the time allotted and allow for flexibility should the need arise.

Careful planning will allow you to integrate STS connections, skills and concepts within a unit and between units in order to maximize class time.

UNIT PRE-PLANNING SHEET



INSTRUCTIONAL/ ASSESSMENT EVALUATION STRATEGIES

There are several instruction, assessment, and evaluation strategies that may be used to promote student learning and the development of skills. This TRM provides several detailed descriptions of strategies, assessment and evaluation ideas. The index to instruction, assessment and evaluation strategies on pages 14–19 is included to assist with course, and unit and daily lesson planning.

The following list contains some strategies, activities and resources that one may use in the selection and sequencing of learning activities.

assignments
audio tapes
audio-visual tapes (videos)

biography
bulletin board displays
brainstorming

cartoons
case study
charts
checklists
collages
computers and programs
concept development
controversial issues
cooperative learning activities
creative writing

decision making debates
demonstrations
dioramas
discussions
displays
drama
drawings

editorials
essays

field studies/trips
films
filmstrips

games
graphs
group work/effectiveness
guest speakers

independent study
interviews
lab - verification or original design
learning centres
lectures
letters
library research projects

magazines
models
murals
music

newspapers
note taking/making

oral presentations, reports
outlining

painting
panels round tables
paraphrasing
performance assessment
perspective identification
photograph study
picture study
plays

poetry
portfolio
position papers
posters
problem solving

questioning

radio
rating scales
reading (content, bias)
records
role playing
reports (oral, written)
resource people

science learning log
scrapbooks
seminars
self-assessment
skills assessment
slides/tape
speeches
storytelling
surveys

tables
tape recording
television
timelines
videotapes
webbing
writing

Adapted from the Senior High Social Studies 10–20–30 TRM, pages 36–88.

Index to Teaching, Assessment and Evaluation Strategies

Teaching Strategy	Instruction/Evaluation Strategy	Page Reference
Teaching for Thinking	Thinking About Thinking Skills in Science Education	S.3A-1
	Why Teach Thinking Skills	S.3A-2
	Changing Role of the Teacher/Student in the Information Era	S.3A-4
	Some Ways to Encourage Thinking Skill Development in Science	S.3A-7
	1. Setting the Stage: Developing an Atmosphere Where Thinking Can Grow	S.3A-7
	2. Planning for the Teaching of Thinking	S.3A-10
	3. Planning Thinking Skill Activities	S.3A-10
	Stage 1 – Beginning exploring, gathering, focusing e.g., brainstorming, elaborating, evaluating	S.3A-11
	Stage 2 – Organizing information, developing categories, concepts and ideas e.g., pattern-making – concept maps, sequence maps, etc.; synthesizing – fantasy fact, hypothetical situations, etc.	S.3A-14
	Stage 3 – Using concepts and information, being thoughtful thinkers e.g., predicting – design an experiment, cause and effect, plus–minus charts; problem resolving, decision making – problem solving elaboration of steps	S.3A-19
	Thinking Skills Planning Chart (master)	S.3A-24
	Issue: Plus/Minus/Interesting Chart (master)	S.3A-25
Teaching for Conceptual Change	A Constructivist Science Teaching Model (learning cycle)	S.3B-6
	Framework Underlying Constructivist Science Teaching Strategy	S.3B-7
	Appendix: The Use of Concept Maps	S.3B-14
Teacher as Facilitator	Discusses the role of the science teacher as a facilitator of the learning of science rather than the expert/lecturer or dispenser of scientific knowledge.	S.3C
Questioning Techniques	Discusses specific questioning strategies: wait time, leveling, probing, chaining, formulating questions.	S.3D

281

Teaching Strategy	Instruction/Evaluation Strategy	Page Reference
Cooperative Learning	Cooperative Learning Planning and Implementing Cooperative Learning Activities for illustrating jigsaw Activities for illustrating group roles Activities for illustrating group games Activities for illustrating STAD (student teams and achievement) Activities for illustrating TGT (teams, games, tournaments) Self assessment form (master)	S.3E-1 S.3E-7 S.3E-9 S.3E-11 S.3E-13 S.3E-14 S.3E-15 S.3E-17
Language for Thinking and Communication	Science Learning Log Spontaneous writing – activities e.g., lesson responses, summarizing a concept, end-of-class summaries, problem solving in writing, clustering Evaluating spontaneous writing More ideas for learning logs Portfolio RAFTS writing assignments Other activities, e.g., stories, rap songs, poem, case study, cartoon, etc. Project Writing process approach to formal writing: pre-writing, drafting, editing Ideas for helping students improve writing skills in senior high science Reading strategies for science materials Speaking/listening Viewing	S.3F-1 S.3F-4 S.3F-10 S.3F-10 S.3F-12 S.3F-15 S.3F-19 S.3F-20 S.3F-20 S.3F-21 S.3F-21
Effective Use of a Research Process	The Continuum of Research Skills and Strategies Planning, information retrieval, information processing, information sharing, evaluation	S.3G-2
Use of Periodicals in the Classroom	Use of Periodicals in the Classroom Copyright Sample "request for permission" letter Copyright permission form	S.3H-1 S.3H-2 S.3H-4 S.3H-5

Teaching Strategy	Instruction/Evaluation Strategy	Page Reference
An STS Context	Learning Activities	
	Demonstrations	S.3I-3
	Lab activities	S.3I-3
	Brainstorming	S.3I-4
	Simulations, e.g., case study, role-playing scenario, interactive debate	S.3I-4
	Topic research or career exploration investigation	S.3I-7
	Learning Contexts:	
	Nature of science sample	
	Lesson 1: a discrepant event	S.3I-8
	Lesson 2: monitoring water quality	S.3I-12
	Science and technology sample lesson: Using sunlight to separate salt from water	S.3I-17
	Social issues of science and technology sample lesson: Should the Oldman River Dam be built?	S.3I-22
Controversial Issues	What Controversial Issues Should be Used in Classrooms?	S.3J-1
	Controversial Issues and the Nature of Science	S.3J-2
	Limitations of Science	S.3J-4
	Controversial Issues and Technology	S.3J-5
	Technology-related controversial issue evaluating medical technology	S.3J-5
	Limitations of technology	S.3J-7
	Decision-making Process	S.3J-8
	Implementing Controversial Issues	S.3J-10
	Suggested room set-up for debate	S.3J-11
	Recommendations to help debate	S.3J-12
	Policy and Legislation	S.3J-13
Thematic Approach	Integrating Science 10-20-30 Around Themes	S.3K-1
	Suggested steps for teaching science from a thematic perspective	
	1. Reflect on the Theme	
	2. Unit Planning	S.3K-7
	3. Lesson planning	S.3K-7
	Unifying Science 10-20-30 Around Major Topics	S.3K-10
	How to unify science around major topics	S.3K-11
	1. Selecting major unifying topics	S.3K-12
	2. Organizing content around unifying topics	S.3K-12
	(samples)	S.3K-12
	3. Building expanded unified courses	S.3K-16
Environmental Connections	Integration of Environmental Concepts in Science Courses	S.3L-1
	Mapping Opportunities for Integration	S.3L-4

Teaching Strategy	Instruction/Evaluation Strategy	Page Reference
Agriculture Connections in Senior High Science	Elements of Living Systems Oxidation-Reduction Reactions Disposal of Animal By-products Regulating Physiological Processes Food Production and Processing The Biosphere Thinking Green Alternative Energy Sources Kinematics and Dynamics Light and Energy Genetics and Adaptation Biological Controls Heat Energy Resources for Agriculture in the Classroom	S.3M-1 S.3M-2 S.3M-2 S.3M-3 S.3M-4 S.3M-5 S.3M-6 S.3M-7 S.3M-7 S.3M-8 S.3M-9 S.3M-10 S.3M-10 S.3M-11
Technology and Media	What are Media and Technology Using media in the science inquiry process/ technological problem solving/research Strategies for Media/Technology Integration The Future of Media and Technologies in Education A Suggested Approach to Using Media and Technologies	S.3N-1 S.3N-4 S.3N-7 S.3N-9 S.3N-10
Traditional and Local Knowledge	The integration of traditional and local knowledge into the teaching of western science	S.3O
Teaching with Gender Balance	Techniques for encouraging girls in the sciences	S.3P
"Microchemistry" and Responsible Disposal	Techniques for reducing chemical quantities and safety disposing of chemicals	S.3Q

Teaching Strategy	Instruction/Evaluation Strategy	Page Reference
Assessment and Evaluation	Definitions: Assessment, Evaluation	S.5-2
	Science Performance Assessment	S.5-4
	Performance assessment strategies	S.5-5
	1. Observing and Questioning	S.5-5
	Informal Observation and Questioning	S.5-6
	Recording Techniques	S.5-6
	Comment Card	S.5-7
	Checklist	S.5-7
	Rating Scale	S.5-8
	Formal Observation and Questioning	S.5-10
	Structured Interviews	S.5-10
	2. Science Problem-Solving Skills	S.5-11
	Initiating and Planning	S.5-11
	Collecting and Recording	S.5-12
	Organizing and Communicating	S.5-12
	Analyzing	S.5-12
	Connecting, Synthesizing and Integrating	S.5-12
	Evaluating the Process or Outcomes	S.5-13
	A Model for the Assessment and Evaluation of Problem-Solving Skills	S.5-14
	Grading Individual Student Performance	S.5-20
	Sample Skill Assessment Evaluation Profile Forms	S.5-21
	Individual Student Profile – Master	S.5-21
	Individual Student Profile – Sample	S.5-22
	Class Profile – Master	S.5-23
	3. Student Self–Assessment	S.5-24
	Oral Presentations Rating Scale	S.5-24
	Self-rating scale for oral presentations	S.5-25
	Listening Self-Assessment Checklist	S.5-25
	Group Activity Self-Rating Scales	S.5-27
	Sample self-rating scale	S.5-27
	Sample group self-rating scale	S.5-28
	Student Report	S.5-28
	Inventories	S.5-29
	Sample personal inventory	S.5-30
	Holistic Scoring and Personal Assessment	S.5-30
	All-or-none scoring	S.5-30
	Focused Holistic Scoring	S.5-30
	Science Product Evaluation	S.5-32
	1. Analytic Scoring	S.5-32
	Laboratory report	S.5-33
	Research project	S.5-33
	Library assignment	S.5-34
	Case studies	S.5-34
	2. Quizzes, Tests and Examination	S.5-34
	3. Science Portfolios	S.5-37

Teaching Strategy	Instruction/Evaluation Strategy	Page Reference
Assessment and Evaluation (continued)	Planning for Student Assessment and Evaluation 1. Course Evaluation Plan 2. Unit Assessment and Evaluation Plan Appendix 1: Attitude Inventories Appendix 2: Library Assignment Appendix 3: Case Study OR Holistic Scoring and Personal Assessment All-or-None Scoring Focused Holistic Scoring Science Product Evaluation 1. Analytic Scoring	S.5-39 S.5-40 S.5-41 S.5-43 S.5-51 S.5-53 S.5-30 S.5-30 S.5-30 S.5-32
Resources	Basic Learning Resources Authorized Teaching Resources Support Learning Resources Other Resources Videodics Software Laboratory Interfaces Teacher Background Print and Nonprint Resources	S.6-3 S.6-6 S.6-8 S.6-10 S.6-17 S.6-19 S.6-20 S.6-24

DAILY LESSON PLAN

The learning cycle is used to outline general learner expectations, specific learner expectations, and to provide a framework for the lesson.

LEARNING CYCLE

GENERAL LEARNER EXPECTATIONS

- themes
- skills
- STS

SPECIFIC LEARNER EXPECTATIONS

- knowledge
- skills
- STS connections

INTRODUCTION

EXPLORATION

DEVELOPMENT

APPLICATION

SIGNIFICANCE

ASSESSMENT AND EVALUATION

It is important to outline the general learner expectations (themes, aspects of the skills framework and STS connections) and specific learner expectations (knowledge, skills and STS connections) to ensure that all are addressed within the unit.

The **introduction** frames the lesson in a manner relevant to the student. Often based on an STS connection, the purpose is to motivate and answer the question: "Why am I learning this?" It could also be linked to the significance of a previous lesson. The introduction may include a relevant newspaper article, challenge questions, development of a concept map, or research activities. Additional suggestions are listed on page 13, *instruction, assessment and evaluation strategies*.

The **exploration** phase involves an activity used to explore a new idea or concept. Exploration activities may include a lab activity, a field trip, a guest speaker, or perspective identification within an article.

The **development** phase is a teacher-directed class discussion in which concepts are developed to describe the results of the initial exploration. Try not to use this time copying prepared notes onto the board: this quickly degenerates into a mindless activity for the students.

The **application** phase involves students applying and stabilizing their learning, relating it to the major concepts, themes and previous learning. This may involve further study and discussion in a cooperative learning group, lab activities, or research projects.

The **significance** of the new learning is further investigated in an STS context. You may choose to build on the STS context provided in the introduction. Teachers facilitate the linkage of student learning with STS applications from their everyday lives.

Assessment and evaluation are an integral part of planning and can be incorporated in any or all phases of the learning cycle. Each evaluation activity should be designed to promote student growth. For additional information see Section 5 – Assessment and Evaluation.

Each evaluation activity should be designed to promote student growth.

A sample learning cycle worksheet has been included for use in daily lesson planning. Abbreviated versions of exemplars provided in the Science 10 and 20-level TRMs are included to illustrate possible lesson flows.

Abbreviated Exemplar illustrating possible lesson flow

COMPARING WEATHER PREDICTIONS Unit 1: Science 10	STORING THERMAL ENERGY Unit 1: Science 10
Introduction *the teacher frames the lesson in a manner that is relevant to the learners*	
Have students explain folklore beliefs about weather prediction.	Show picture of pavement/lush green forest area. Where would you prefer to work if air temperatures were 40°C? Why?
Exploration *an activity is used to explore the new idea or concept*	
Examine almanacs, newspaper reports, simple weather forecasting instruments.	Brainstorming Groups: Read activities, identify variables, select materials. Activity: Identify materials that are suited for collection and storage of solar energy.
Development *the teacher guides discussion as students develop concepts to describe the results of the initial exploration*	
Focused discussion – questions related to almanac use, accuracy of almanacs and how data are collected by weather forecasters.	Teacher-directed class discussion – focused questions re: heat capacity.
Application *students apply and stabilize their learning, relating it to the major concepts, themes and previous learning*	
Assignment involving comparing weather predictionsa nd weather forecasters with students' own predictions.	Explain: the use of black piping to heat water for swimming pool; ceramic tile used on space shuttle. Build: model of solar house which uses hot-water heating.

Abbreviated Exemplar illustrating possible lesson flow

COMPARING WEATHER PREDICTIONS Unit 1: Science 10	STORING THERMAL ENERGY Unit 1: Science 10
Significance *the significance of the new learning is developed in an STS context*	
Comparison of technological data collection via satellite and radar scans; statistical analysis of data in order to make predictions (almanacs). Emphasize the limitations of scientists—even with advanced technology to provide all the answers.	Water's high heat capacity is ideal for cooling systems – thermal pollution. Impact of cities (cement structures) or deforestation on weather patterns.

Assessment and Evaluation *strategies used to assess and evaluate new learning.*	
Rating scale to evaluate comparison assignment.	Focused holistic scoring.

Abbreviated Exemplar illustrating possible lesson flow

STUDYING INFRARED PHOTOGRAPHY **Unit 1: Science 10**	**BIOGEOCHEMICAL CYCLES** **Unit 1: Biology 20**
Introduction *the teacher frames the lesson in a manner that is relevant to the learners*	
Pose challenge questions: How do weather satellites: – produce night-time images of cloud cover? – determine water and air temperatures? – distinguish the boundaries between cold and warm fronts?	Research and prepare charts/tables of basic food costs world-wide (developed and underdeveloped countries) with a focus on inorganic/organic fertilizers and their costs.
Exploration *an activity is used to explore the new idea or concept*	
Interpret remote sensing pictures. How are infrared pictures different from conventional pictures?	Have a class field trip to a local fertilizer manufacturer. Focus on cost of fertilizer production and cost to consumer (farmer).
Development *the teacher guides discussion as students develop concepts to describe the results of the initial exploration*	
Discuss: specially sensitized film; colours in thermograph indicate relative warmth.	Carbon, nitrogen and phosphorus can come from a variety of natural, societal and industrial sources. Disruptions in natural cycles may be caused by human activities.
Application *students apply and stabilize their learning, relating it to the major concepts, themes and previous learning*	
Cooperative learning groups study a specific aspect of infrared photography.	Activity to test the relative amounts of nitrogen, phosphorus and potassium in a variety of commercial fertilizers and garden compost.

Abbreviated Exemplar illustrating possible lesson flow

STUDYING INFRARED PHOTOGRAPHY **Unit 1: Science 10**	BIOGEOCHEMICAL CYCLES **Unit 1: Biology 20**

Significance *the significance of the new learning is developed in an STS context*

Thermal imaging techniques help scientists formulate theories and advance understanding of ecology, geography, geology, physiology and pathology. Desertification can be monitored by remote sensing satellites to explain why famines have become so common-place in northern Africa.	Recreational impact of lake overproduction (eutrophication). Natural vs "organic" farming.

Assessment and Evaluation *strategies used to assess and evaluate new learning.*

Group-rating scale for cooperative learning activity.	Individual student profile – scientific problem-solving skills.

292

Learning Cycle Worksheet

The themes of this unit of study are: | | Topic: ____________

The aspects of the **skills framework** emphasized are:

Initiating and Planning	Analyzing

Collecting and Recording	Connecting, Synthesizing and Integrating

Organizing and Communicating	Evaluating the Process or Outcomes

The **STS connections** emphasized are:

The **specific learner expectations** addressed are:

Knowledge

Skills

STS connections

293

Introduction *the teacher frames the lesson in a manner that is relevant to the learners*

Exploration *an activity is used to explore the new idea or concept*

Development *the teacher guides discussion as students develop concepts to describe the results of the initial exploration*

Application *students apply and stabilize their learning, relating it to the major concepts, themes and previous learning*

Significance	*the significance of the new learning is developed in an **STS** context*

Assessment and Evaluation	*strategies used to assess and evaluate new learning.*

ASSESSMENT AND EVALUATION

by Karen Slevinsky

INTRODUCTION

The vision for the new high school science programs requires students to focus on learning the interconnecting ideas and principles of science, and:

- develop methods of inquiry that characterize science
- engage in learning activities that provide experience related to their world
- assume increased responsibility for their own learning by being active learners.

This vision can be realized by providing an assessment and evaluation process that is authentic and supports the rationale and philosophy of the science programs. Such a process should provide students with an opportunity to show the level to which they have achieved the intended learning expectations. There must be a close tie between the assessment and evaluation strategies and the intended curriculum so that teachers are better able to determine student achievement levels. These should strive to reflect learning in a real world environment as well as contribute to good teaching and learning.

There must be a close tie between the assessment and evaluation strategies and the intended curriculum so that teachers are better able to determine student achievement levels.

An assessment and evaluation plan which encourages sound teaching and learning processes is based on these three principles:

- Assessment and evaluation are based on clear expectations for student performance.
- Good teaching requires effective assessment and evaluation strategies.
- Assessment and evaluation recognize the central role of language and learning.

Clear Expectations for Student Performance

The learning expectations that form the basis for both instruction and assessment and evaluation of the science programs are made explicit in the various Programs of Study. These expectations provide the basis for establishing performance standards and the designing of assessment and evaluation strategies. The specifications and performance standards of such strategies must ensure fidelity with what the students are expected to have learned and how well they are expected to have learned it. The assessment or evaluation strategy is ***valid*** when it is based on the learning expectations in the Programs of Studies.

The assessment or evaluation strategy is valid when it is based on the learning expectations in the Programs of Studies.

Student evaluation in science refers to a systematic approach to forming judgments about a student's level of achievement based on the following criteria:

- understanding of the *key concepts and principles of science.*
- development of the *skills* related to *science inquiry, problem solving* and *decision making.*
- development of *positive attitudes* about science.

Good Teaching and Effective Assessment and Evaluation Strategies

A sound assessment and evaluation program should focus teaching on those learning outcomes considered important to the development of scientific literacy by providing clear course expectations and performance standards, sample test items with scoring criteria, annotated samples of student work as well as examples of other assessment and evaluation strategies. Fair student assessment and evaluation requires adequate planning and provision of assessment and evaluation criteria to students. The assessment and evaluation strategy must vary as the purpose for assessment or evaluation varies. A variety of assessment instruments to measure performance, and a variety of strategies to complete product evaluation are called for to reflect the different purposes.

The Role of Language in Learning

There is an awareness in Alberta schools of the critical role of language in learning. The development of language skills is necessary, as these allow the students to communicate their achievement in science. A more clearly articulated sense of the role of language can be promoted through the use of class discussions, student projects, learning logs, extended response questions and self-evaluation.

DEFINITIONS

Assessment is the process a teacher uses to determine how effective a student is at performing science-related activities. One form of assessment measures student performance in the process of "doing science". It, therefore, will be referred to as *performance assessment.* Performance assessment includes assessing student performance in group work, laboratories, communication or other activities that de-emphasize rote learning.

Evaluation is "a summing-up process" in which *value judgments* play a large part in determining student achievement with respect to the outcomes of the course of studies. It may include evaluating written reports, essays, projects, laboratory reports, quizzes, tests and examinations. Evaluation may be formative, summative or both.

Formative evaluation is the determination and continuous monitoring of the level of student understanding and development of skills and attitudes. The nature of these strategies, such as observations, student interviews, or specially prepared tests, is *diagnostic*. Formative evaluation instruments are designed to provide students with feedback to reinforce learning and teachers with information useful in planning more effective learning strategies. The results obtained from these should not become part of an individual student's record, although the teacher may find formative evaluation provides useful background for appropriate comments on the student's report card.

Summative evaluation is designed to determine the extent to which the instructional objectives of a course have been achieved and is used primarily for *assigning grades* related to student performance. The results obtained from the use of an assessment instrument, such as a test or quiz, provides information which allows teachers to make judgments about the quality of student performance. Summative evaluation forms the basic measure of achievement for an individual student in relation to the attainment of learner expectations providing information which allows decisions about granting credit or promotion.

Some strategies may be summative for a student, yet formative for the teacher. The unit test that becomes part of the student's final grade is summative for the student. The class results on that same test can be used by the teacher to determine such things as the success of teaching with a new curricular emphasis or basic resource, or whether a class or particular student needs remedaition, enrichment or extension activity for a particular unit. The unit test is then formative for the teacher. To be truly formative for the student, a test must have the option of a rewrite after critical review of the test, and time allowed to master skills or concepts that were handled poorly.

Some strategies may be summative for a student, yet formative for the teacher.

Students Doing Science

Performance assessment involves giving an individual student, or group of students, a science process-related task that may take from half an hour to several days to complete or solve. The objective of the assessment is to observe the way students work as well as to look at the completed task or product. This type of assessment can provide an additional tool for diagnosing learning difficulties as well as provide valuable information used to improve the program.

The task might be taken from any science content area within the curriculum. Focusing on a single student or group of students, the assessment may take many forms, such as:

- presenting students with a problem related to what they are already doing in class, and listening to the responses
- observing what students do and say; watching for selected characteristics; making anecdotal records
- interviewing students during or after an investigation
- collecting student writing, either as it is generated by the science investigation or in response to an additional question
- observing the performance of a process skill task related to science inquiry or problem solving (e.g., laboratory station tasks, physical model building).

Advantages of Performance Assessment

Looking at student performance gives information about their ability to:

- reason soundly and raise questions
- persist, concentrate and work independently
- observe, infer, formulate hypotheses and predict
- think flexibly, changing strategies when they do not work
- use process-related materials and equipment
- work together in groups
- communicate and use scientific language through discussing, writing and explaining ideas in their own words
- design and conduct their own experiments and investigations

- collect, organize and display information
- get excited about science.

(Adapted from *Assessment Alternatives in Mathematics*, a booklet from the California Mathematics Council.)

PERFORMANCE ASSESSMENT STRATEGIES

1. Observing and Questioning

Observing and questioning students while they are actually engaged in an activity gives teachers the opportunity to assess directly the level of concept, skill and attitude development of students within a particular unit of study. This assessment strategy can be done ***informally*** by observing the level of involvement of students or a class in an activity, or ***formally*** through structured interviews with individual students.

Observing and questioning students while they are actually engaged in an activity gives teachers the opportunity to assess directly the level of concept, skill and attitude development of students within a particular unit of study.

Observation Techniques:

- Students should not be distracted by the teacher's attempts to observe them.
- Teachers can observe both the behaviour of students working independently or in a group setting.
- Observations should be focused on one aspect of a particular activity; e.g., leadership skills in a group setting.
- Specific tasks that are to be observed within an activity should be decided beforehand.
- Individual students or a small group of students should be selected for observation at any one time.
- Teachers should be flexible and be able to note other significant behaviours which have not been included in the original assessment plan.
- Comment cards and checklists are useful ways of recording observations.

The purpose of *questioning* is to help the teacher evaluate the students' own verbal responses as assessment indicators. The questions should help reveal the students' thinking processes concerning some aspect of the current activity. For example, students working in pairs to design an experiment to test a prediction could be asked the following questions.

- What science concepts will you need to understand in order to design an experiment to test the prediction?
- Can you describe the prediction being tested by this experiment?
- Are you satisfied that the prediction is worded in a way that will add to our understanding of the hypothesis?
- Is it possible to test the prediction, using your experimental design?
- Have you identified the manipulated, responding and controlled variables?
- What materials will be required to test the prediction, using your experimental design?
- How will you record your observations and what do you hope to do with your data?
- How do you feel about planning this experiment yourself?
- Do you feel you can carry out this plan with your partner?
- What science concepts will you need to understand in order to reach some conclusions in this experiment?

Informal Observation and Questioning

This assessment strategy uses the direct observation of students, small groups or a class.

This assessment strategy uses the direct observation of students, small groups or a class, to provide general information about the level of performance on particular tasks within an activity. Examples of such activities might include problem solving, model building, issue resolution, case study analysis, or planning a presentation.

Suggested methods for recording include comment cards, checklists, or rating scales.

The observing and questioning information should be ***recorded*** briefly and objectively as soon as possible after observation. Suggested methods for recording include comment cards, checklists, or rating scales. They should be created to meet the needs of the student, group and situation. They may be revised or used as guides to develop scales tailored to specific situations. A general outline for creating them follows:

- Determine the goal(s) of performance or attitude you wish to assess. Select those which cannot be evaluated more easily by other means.
- List specific student actions, thoughts, or attitudes that would indicate the achievement of the goal or goals.
- On the checklist or rating scale, write items that describe the specifics of the selected actions, thoughts, or attitudes. If a rating scale is used, select an appropriate scale.

The ***comment card*** may be used to indicate specific achievements in concept and skill development as well as diagnosing areas that require special attention. Personal surveys of individuals or groups may be well served by the use of a comment card.

Sample Comment Card: Problem-Solving Activity

	Activity: Problem Solving
Student: ____________________	**Date:** ____________________

Comments: Identified problem clearly but had difficulty in actual planning of the investigation. Uncomfortable with the prospect of having to design rather than follow a given plan. Cooperative in the group and responded well to guiding questions. Persevered with encouragement.

The ***checklist*** may be used to record observations of student or group behaviour and is a personal appraisal of capabilities and attitudes toward the science environment. Specific areas of development may include the ability to solve problems, contribution to group activities, willingness to work cooperatively and contribution of ideas to the group or the group to the class.

Sample Checklist: Problem Solving Activity

Activity: Problem Solving

Student: ______________________ Date: ______________________

______ 1. Likes to solve problems

______ 2. Works cooperatively with others in the group

______ 3. Contributes ideas to group problem solving

______ 4. Perseveres – sticks with a problem

______ 5. Tries to understand the problem

______ 6. Can deal with data in solving problems

______ 7. Thinks about which strategies might help

______ 8. Is flexible – tries different strategies

______ 9. Checks data and/or results for accuracy

______ 10. Can describe/analyze results or come to an appropriate conclusion/decision

Adapted from *How to Evaluate Progress in Problem Solving*
National Council of Teachers of Mathematics, 1987.

A ***rating scale*** may be used when a specific concept, skill or attitude is being assessed and could be used in conjunction with a similar student self-evaluation technique. Students could realize awareness of their development in relationship with the teacher appraisal. Depending on the nature of the assessment, the rating scale may be any scale from complex to relatively brief.

Sample Rating Scale: Science Inquiry Activity

Activity: Science Inquiry

Student: ______________________ Date: ______________________

	Frequently	Sometimes	Never
1. Selects appropriate solution strategies	____	____	____
2. Accurately implements solution strategies	____	____	____
3. Tries a different solution strategy (without help from the teacher) when stuck	____	____	____
4. Approaches science inquiry in a systematic manner	____	____	____
5. Shows a willingness to use science inquiry processes	____	____	____
6. Demonstrates self-confidence	____	____	____
7. Perseveres in attempts	____	____	____

Sample Rating Scale: Participation in Classroom Oral Activities

NAME______________________ DATE____________to____________

INSTRUCTIONS: Use the following scale to rate each aspect of classroom behaviour. Space is provided at the bottom for a summary comment and an overall score or rating if one is desired. Note that the overall rating need not be the "average" of the individual items – some items may be more important than others and thus should be weighed more heavily in determining the overall score.

Rating Criteria:

1 Never. May be obstructive or uncooperative.
2 Rarely. Usually needs prompting.
3 Occasionally. Varies by activity or topic.
4 Frequently. Observed in a variety of activities.
5 Characteristic of this student. A definite strength.

1. Answers questions in class.	1	2	3	4	5
2. Volunteers observations or ideas.	1	2	3	4	5
3. Asks questions for clarification.	1	2	3	4	5
4. Asks questions or offers observations which prompt or extend class discussion.	1	2	3	4	5
5. Follows oral instructions accurately.	1	2	3	4	5
6. Supports and encourages other students.	1	2	3	4	5
7. Listens attentively and courteously to the teacher.	1	2	3	4	5
8. Listens attentively and courteously to other students.	1	2	3	4	5

Summary Comments and Score

Enhancing and Evaluating Oral Communication in Secondary Grades, British Columbia Ministry of Education, 1988.

Formal Observation and Questioning

Structured Interviews involve formal observation and questioning of a student during a science inquiry session.

Structured Interviews involve formal observation and questioning of a student during a science inquiry session. It is much more structured than the previously discussed informal methods, with a definite science inquiry task assigned and very specific questions to the student regarding the mental processes the student is going through and the feelings associated with such activity. A diagnostic interview plan must be designed to identify where a student is having difficulty, allowing for remedial planning. This method requires privacy, considerable time and effort, and a certain degree of rapport with the student. Recording of the interview on audio or videotape, writing an anecdotal report, or completing a rating scale or checklist is necessary to facilitate analysis. This formal method can be useful when other methods have failed to discover the student's difficulty.

In designing an interview the teacher selects an assignment for the student to do during the interview.

In *designing an interview* the teacher selects an assignment for the student to do during the interview. For example, the student may be asked to identify the scientific and economic perspective in a newspaper article on a recent oil spill. The SQ3R method (see next page) has been taught in class and practised at this point, but this student is experiencing great difficulty in handling such assignments. A set of questions should be designed to probe the inquiry strategy used by the student, and the feelings associated with the process. Some of the areas the questions could explore are:

Sample Interview Questions

1. Can you describe what you are asked to do in this assignment?

2. What methods might you use to do this assignment?

   What method might work?

   How will you decide which method to use?

3. What specific information will you locate and use from this article?
   How do you intend to use this information?

4. What steps will you go through in completing this assignment?

5. When you finish, how will you evaluate the quality of your work?

Each phase of the assignment can be probed as the student works through the inquiry (investigation, problem, or issue). The information gained from the interview can be used to help the teacher and student determine the difficult areas and the necessary remedial action.

The SQ3R Study Method for Studying and Textbook Reading

Survey	what you will be reading. Take 1 to 2 minutes to scan the assignment; i.e., title, headings, summary paragraphs, review questions. You will then be better able to relate what you already know to the new material.
Question	what you will be reading. Turn the first heading into a question by asking "How?", "What?", "Why?", or "Who?" about it. Then you will know what you need to find out while reading.
Read	from the beginning to the end. Keep your questions in mind and be alert for possible answers.
Recite	the information you have learned. Ask yourself the question, then tell yourself the answer. It is this step that helps you most to learn what you have read. The best way to recite is to take *brief* notes in outline form, listing the question on the left-hand side of your paper and the answer on the right-hand side. The answer should summarize the main idea of the section, followed by important details. This will help you later to review.
Review	to test your learning and to make sure that you remember information until you need it. Cover up the right-hand side of your notes. Ask yourself the questions on the left-hand side, and see if you know the answers. If you don't, look over your notes again.

2. Science Skills Framework

The skills framework presented here is from the General Learner Expectations to be found in the Senior High Science Programs of Study. The criteria for assessment and evaluation of scientific inquiry are based upon this skills framework. Two assessment models, the first for the assessment and evaluation of these skills, and the second for grading individual performance based upon the assessment, follow.

- Initiating and Planning
  - identify and clearly state the problem or issue to be investigated
  - differentiate between relevant and irrelevant data or information
  - assemble and record background information
  - identify all variables and controls
  - identify materials and apparatus required
  - formulate questions, hypotheses and/or predictions to guide research

The criteria for assessment and evaluation of scientific inquiry are based upon this skills framework.

- Collecting and Recording
  - carry out and modify the procedure, if necessary
  - organize and correctly use apparatus and materials to collect reliable experimental data
  - accurately observe, gather and record data or information according to safety regulations and environmental considerations

- Organizing and Communicating
  - organize and present data (themes, groups, tables, graphs, flow charts and Venn diagrams) in a concise and effective form
  - communicate data more effectively, using mathematical and statistical calculations where necessary
  - express measured and calculated quantities to the appropriate number of significant digits and use appropriate SI units for all quantities
  - communicate findings of investigations in a clearly written report

- Analyzing
  - analyze data or information for trends, patterns, relationships, reliability and accuracy
  - identify and discuss sources of error and their effect on results
  - identify assumptions, attributes, biases, claims or reasons
  - identify main ideas

- Connecting, Synthesizing and Integrating
  - predict from data or information
  - formulate further testable hypotheses supported by the knowledge and understanding generated
  - identify further problems or issues to be investigated
  - identify alternatives for consideration
  - propose and explain interpretations or conclusions
  - develop theoretical explanations
  - relate the data or information to laws, principles, models or theories identified in background information
  - answer the problem investigated
  - summarize and communicate findings
  - decide on a course of action

- Evaluating the Process or Outcomes
  - establish criteria to judge data or information
  - consider consequences and perspectives
  - identify limitations of the data or information, and interpretations or conclusions, as a result of the experimental/research/project/design
  - suggest alternatives and consider improvements to experimental technique and design
  - evaluate and assess ideas, information and alternatives

The criteria for assessing the science process skills embedded in this framework can be found on the following six pages.

A Model for the Assessment and Evaluation of Science Process Skills (Student Evaluation Branch, 1992)

Criteria for Assessing Science Process Skills
A. Initiating and Planning

LEVEL 1 Grades 1–3	LEVEL 2 Grades 4–6	LEVEL 3 Grades 7–9	LEVEL 4 Grades 10–12
• Proposes a simple problem statement when initiated to do so • Background information must be supplied • Identifies those things that change and those that stay the same • Guesses about the outcomes • Identifies simple materials and equipment to be used • Follows directions as provided	• Proposes a simple problem statement • Background information is supplied from teacher's or student's own experience • Identifies variables and controls • Makes "educated" guesses • Identifies materials and equipment to be used • Is able to assemble simple apparatus • Follows directions as provided • Is able to write simple procedural statements • Prepares observation charts, tables and diagrams as directed by teacher	• Proposes a problem to be investigated • Background supplied by teacher, reference material or student's own experience • Identifies controls, manipulated variables and responding variables • Makes a prediction and/or suggests a simple hypothesis • Identifies the materials and equipment to be used • Assembles simple apparatus • Develops and organizes a simple written procedure • Prepares charts, diagrams, graphs and performs calculations as outlined by teacher	• Clearly states the purposes and problem to be investigated • Forms an appropriate hypothesis and prediction • Prepares the necessary background information from references, research, discussion and/or past experience • Designs an investigation • Identifies the controls and variables • Identifies and names the materials and equipment to be used • Designs and writes procedures that are clear and detailed • Assembles and designs or modifies simple apparatus • Prepares observation charts, diagrams and graphs

Criteria for Assessing Science Process Skills
B. Collecting and Recording

LEVEL 1 Grades 1–3	LEVEL 2 Grades 4–6	LEVEL 3 Grades 7–9	LEVEL 4 Grades 10–12
• Follows a simple procedure • Correctly uses apparatus and materials as directed by teacher • Collects data, using concrete, tangible objects • Records data in sentence form or in simple charts that have been constructed • Is aware of safety and environmental concerns • Follows stated safety concerns	• Follows a simple procedure • Correctly uses apparatus and materials • Collects tangible objects • Carries out simple measurements • Records data in numerical and non-numerical form • Is able to use and construct simple charts • Is aware of safety and environmental concerns • Follows stated safety concerns	• Follows a given procedure and is able to suggest modifications when asked to do so • Correctly uses materials and apparatus • Accurately collects and records relevant data including the correct units with respect to measured data • Shows appropriate safety and environmental concerns in the use, care and maintenance of materials and apparatus • Is able to locate appropriate safety regulations • Actively participates in teacher-directed discussion of safety and environmental issues	• Follows a given procedure and modifies the procedure when necessary • Consistently uses standard apparatus and materials correctly • Accurately collects and records data using the appropriate units • Demonstrates appropriate standards of safety • Is able to suggest modifications to procedures to minimize environmental damage, where applicable

Criteria for Assessing Science Process Skills
C. Organizing and Communicating

LEVEL 1 Grades 1–3	LEVEL 2 Grades 4–6	LEVEL 3 Grades 7–9	LEVEL 4 Grades 10–12
• Organizes data in sets of concrete objects	• Organizes data in sets of objects • Provides a basis for the organization of data sets • Constructs simple graphs to represent the data • Performs basic mathematical calculations • Identifies, with teacher assistance, errors and inaccuracies	• Organizes data in the form of sets, themes and/or tables • Provides a basis for and suggests alternatives for the organization of data • Is able to construct graphs and/or tables to represent the data • Performs basic mathematical calculations • Identifies errors and discrepancies in data or collection procedures • Takes part in teacher-directed discussion of scientific inaccuracies	• Organizes data accurately • Is able to represent data, using appropriate graphs and tables • Performs relevant and required mathematical calculations, where applicable • Expresses measured and calculated quantities to precision, where applicable

Criteria for Assessing Science Process Skills
D. Analyzing

LEVEL 1 Grades 1–3	LEVEL 2 Grades 4–6	LEVEL 3 Grades 7–9	LEVEL 4 Grades 10–12
• Correctly identifies patterns within the data • Identifies, with teacher assistance, relationships	• Assesses patterns and trends that are conceptually presented by the data • Identifies simple cause and effect relationships • Identifies, with teacher assistance, the sources of error in data collection and manipulation • Identifies, with teacher assistance, the effect of errors on results	• Assesses patterns, trends and simple relationships • Identifies the sources of error in data collection and manipulation • Suggests amendments to procedures and/or data manipulation in order to rectify results	• Assesses patterns, trends and relationships resulting from collected and from manipulated data • Expresses accuracy qualitatively and/or quantitatively (percent difference), where applicable • Identifies the sources of error in data collection and manipulation • Identifies the assumptions relating to measurement and/or analysis • Determines the reliability of the data • Answers the problem

Criteria for Assessing Science Process Skills
E. Connecting, Synthesizing and Integrating

LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5
• Provides a simple but not necessarily appropriate answer to the problem investigated, based on results obtained	• Provides a simple answer that is appropriate for the problem investigated and results obtained • Attempts to relate results to knowledge that is not specifically related to scientific theories or laws	• Provides an appropriate answer to the problem investigated, based on results obtained • Relates results, with teacher assistance, to applicable theories and/or laws	• Relates the data to laws, principles, models or theories identified in background information and/or in broader context • Proposes and explains interpreta-tions or conclusions • Develops theoretical explanations • Considers consequences and perspectives • Evaluates assumptions and effects of bias • Evaluates the total investigation in terms of reliability and validity	• Restricts, revises or replaces an unacceptable scientific concept

Criteria for Assessing Science Process Skills
F. Evaluating the Process or Outcomes

LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5
• Attempts to explain results of the problem investigated	• Attempts to explain results of the problem investigated • Attempts to draw conclusions where applicable and when prompted	• Is able to explain the results obtained in light of the problem being investigated • Draws conclusions and attempts to explain them • Discusses the limitations of the data collected, interpretations, and/or conclusions • Discusses, when prompted, the validity of results • Discusses, when prompted, alternatives and/or improvements to the experimental design	• Evaluates the prediction and concepts • Identifies limitations of the data and information, interpretations, or conclusions, as a result of the design of the experiment, research, or project • Suggests alternatives and considers improvements to experimental technique and design	• Establishes criteria to judge the design, prediction, and concepts • Considers consequences and perspectives • Evaluates assumptions and effects of bias • Evaluates the total investigation in terms of reliability and validity

Grading Individual Student Performance Based on Assessment of Science Process Skills (Student Evaluation Branch, 1992)

This assessment model provides a framework clarifying criteria against which to judge student achievement and thereby enable students to raise their achievement in scientific problem-solving skills. The information obtained provides a means for diagnosing student difficulties and illustrating means by which students can progress toward the course objectives for science process skills. The overall performance of a student over the term of the course will provide a profile from which a grade can be assigned.

The activities, assignments, reports and laboratory exercises carried out over the term of the course, which contribute to the overall development of science process skills, are to provide the content on which to base assessment of student achievement in problem-solving skills.

The achievement recorded for each student needs to be turned into a mark that will reflect that achievement and contribute to the student's final grade. This mark should be independent from other mark components, such as quizzes and tests, in that it should reflect the practical component that involves student activity in carrying out the course.

At this time, the suggestion is that this component represent 20% of the final grade.

One possible means of generating this mark is as follows:

For Grade 12 Students	
Level 4 Performance	
Excellent performance for all six components of the skills framework	20%
Excellent performance for half the components of the skills framework and a satisfactory performance for the others	15%
Satisfactory performance for all six components of the skills framework	10%
For Grade 11 Students	
Level 4 Performance	
Satisfactory performance or higher for all six components of the skills framework	20%
Level 3 Performance	
Excellent performance at all six components of the skills framework and some evidence of Level 4 performance	15%
Excellent performance for half the Level 3 components of the skills framework and a satisfactory performance for the others	10%

For Grade 10 Students	
Level 3 Performance	
Excellent performance for all six components of the skills framework	20%
Excellent performance for half the components of the skills framework and satisfactory performance for the others	15%
Satisfactory performance for all six components of the skills framework	10%

This scheme requires teacher judgment with respect to assessing the student's performance against the criteria statements.

To assess the students' performance in science inquiry or problem-solving skills, individual student profiles should be kept. As various skills are performed they can be assessed as L (not adequate), S (satisfactory) or E (excellent) for the respective level considered. The criteria for assessment of the skills required of students at each level are provided on the following pages.

Sample Skill Assessment and Evaluation Profile Forms (Student and Class)

Individual Student Profile For: ____________________

Directions for use:

Record the level of achievement demonstrated by the student on each of the six components of the skills framework. This is to be done over a series of activities during the term of the course. To be recorded as having achieved a particular level within one of the six components of the skills framework the student must demonstrate the achievement at least twice.
To be assigned a satisfactory level of achievement for problem solving, the student must have a satisfactory achievement in all six components for that level.

L – achievement is not adequate for this level
S – achievement is satisfactory for this level
E – achievement is excellent for this level

Skills Framework Components	Level 1			Level 2			Level 3			Level 4		
	L	S	E	L	S	E	L	S	E	L	S	E
A. Initiating and Planning												
B. Collecting and Recording												
C. Organizing and Communicating												
D. Analyzing												
E. Connecting, Synthesizing and Integrating												
F. Evaluating the Process or Outcomes												

Sample Individual Student Profile: Megan Lewis

Level Four: Science Skills Components

Date	Laboratory	A	B	C	D	E	F
Feb 12/92	R of Diff		S				
Feb 19/92	Osmosis				E		
Feb 25/92	Enzymes		S				
Feb 28/92	Carbos	L					
Mar 03/92	Proteins	E					
Mar 16/92	Digestion Data						

Class Profile

Skills Framework Components

A. Initiating and Planning
B. Collecting and Recording
C. Organizing and Communicating
D. Analyzing
E. Connecting, Synthesizing and Integrating
F. Evaluating the Process or Outcomes

Record the highest level a student has achieved, at least twice over the term of the course, using the most appropriate indicator **L, S** or **E** where:

L – achievement is not adequate for this level
S – achievement is satisfactory for this level
E – achievement is excellent for this level

Student's Name	Science Skills Components	Overall Assessment (out of 20%)

Teacher's Signature: ____________________ Date: ______________

3. Student Self-Assessment

Students can provide self-assessment data which can be useful to themselves and to the teacher. The usefulness of such assessments depends on how candidly they report their feelings, beliefs, intentions and thinking patterns. Such information plays a role in fully evaluating progress toward the learner expectations of the program, particularly the attitude and skill components.

There are various types of student self-evaluation strategies, such as student reports, listening self-evaluation checklists, oral presentation self-rating scales and group self-evaluation scales

Oral Presentations Rating Scales

It is especially important, in reducing the stress accompanying oral presentations, that students be well prepared and realize their state of preparation or readiness.

The success of any assignment depends on the students' involvement and interest in it. Students may become more successful by a self-awareness of their commitment to the topic of the assignment. It is especially important, in reducing the stress accompanying oral presentations, that students be well prepared and realize their state of preparation or readiness. Oral presentation self-rating scales will aid students in realizing the quality of their work.

A rating scale for classroom oral activity gives the teacher a more quantitative measure of the participation of individual students in these activities. This participation record concentrates on how the student reacts to the classroom behaviour and how well the student becomes part of it.

Self-Rating Scale for Oral Presentations

Directions: Indicate how satisfied you feel about the following features of your topic, preparation and presentation by checking the appropriate line.

	NOT AT ALL	A LITTLE	QUITE	VERY	EXTREMELY
TOPIC.					
Interesting to me	____	____	____	____	____
Interesting to audience	____	____	____	____	____
Appropriate for assignment	____	____	____	____	____
PREPARATION. I was able to:					
Find sufficient information	____	____	____	____	____
Select the information that was appropriate for my speech	____	____	____	____	____
Organize my ideas so the audience could follow easily	____	____	____	____	____
Develop an effective opening	____	____	____	____	____
Develop an effective closing	____	____	____	____	____
Prepare useful note cards	____	____	____	____	____
Practise until I was confident about my presentation	____	____	____	____	____
PREPARATION. I was able to:					
Feel confident and poised	____	____	____	____	____
Speak clearly	____	____	____	____	____
Speak with expression	____	____	____	____	____
Speak fluently with few pauses or hesitations	____	____	____	____	____
Make contact with the audience	____	____	____	____	____
Use my notes effectively	____	____	____	____	____
Follow the plans I had made	____	____	____	____	____

Listening Self-Assessment Checklist

Listening self-assessment checklists may be either of a general nature to allow the students to get a feeling for the classroom environment, or specific to give the students feedback on their reaction to the classroom environment. For example, students who don't always listen carefully may find, through the self-evaluation experience, they are always talking or listening to friends. Samples of general and specific listening self-assessment checklists follow.

General Checklist

Name______________________________ Date______________________________

1.	I listen carefully when my teacher gives instructions.	ALWAYS	USUALLY	SOMETIMES	HARDLY EVER
2.	I sit where I can see and hear.	ALWAYS	USUALLY	SOMETIMES	HARDLY EVER
3.	I start thinking about other things and lose track.	ALWAYS	USUALLY	SOMETIMES	HARDLY EVER
4.	I try to ignore distractions around me.	ALWAYS	USUALLY	SOMETIMES	HARDLY EVER
5.	I'm often too tired to pay close attention.	ALWAYS	USUALLY	SOMETIMES	HARDLY EVER
6.	It is often too hot or too cold in the room.	ALWAYS	USUALLY	SOMETIMES	HARDLY EVER
7.	I pay attention because I need to pass the course.	ALWAYS	USUALLY	SOMETIMES	HARDLY EVER
8.	I talk to my friends instead of listening to the teacher.	ALWAYS	USUALLY	SOMETIMES	HARDLY EVER
9.	The classroom is too noisy.	ALWAYS	USUALLY	SOMETIMES	HARDLY EVER
10.	I'm too worried about other problems to pay attention in class.	ALWAYS	USUALLY	SOMETIMES	HARDLY EVER

Specific Checklist

1.	Do I sit where I can hear the teacher?	ALWAYS	USUALLY	SOMETIMES	HARDLY EVER
2.	Do I dress appropriately so that the room temperature is comfortable?	ALWAYS	USUALLY	SOMETIMES	HARDLY EVER
3.	Do I talk and listen to my friends instead of paying attention to the teacher?	ALWAYS	USUALLY	SOMETIMES	HARDLY EVER
4.	Do I ask questions when I do not understand?	ALWAYS	USUALLY	SOMETIMES	HARDLY EVER
5.	Do I "turn off" my listening if the ideas seem difficult?	ALWAYS	USUALLY	SOMETIMES	HARDLY EVER
6.	Do I daydream a lot in class?	ALWAYS	USUALLY	SOMETIMES	HARDLY EVER
7.	Am I too tired to pay attention?	ALWAYS	USUALLY	SOMETIMES	HARDLY EVER
8.	Does it matter if it is the first or last block of the day?	ALWAYS	USUALLY	SOMETIMES	HARDLY EVER
9.	Is there a lot of outside noise?	ALWAYS	USUALLY	SOMETIMES	HARDLY EVER
10.	Do I blame the teacher instead of trying to solve the problem?	ALWAYS	USUALLY	SOMETIMES	HARDLY EVER

Enhancing and Evaluating Oral Communication in Secondary Grades, British Columbia Ministry of Education, 1988.

Group Activity Self-Rating Scales

The success of a group activity depends on the involvement and generous participation of all the members of the group. A self-rating scale can help students understand the degree to which they are committed to the activity and allow them the opportunity to improve. An activity rating scale seeks information, such as students' role, attention to task, sharing of ideas and listening skills.

A group of students can learn about the anticipated success of an activity by analyzing information gathered from a group self-rating scale. This type of assessment focuses on information, such as nature of the task, sequencing of activities, relationships within the group, degree of participation and type of group leadership style.

Group activity rating scale samples follow:

Sample Self-Rating Scale

NAME:

ACTIVITY:

DATE:

	NOT AT ALL	SOMEWHAT	EXTREMELY
1. How clear were you about your role in this group?	☐	☐	☐
2. How well were you able to focus your attention on the task?	☐	☐	☐
3. How completely did you share your ideas?	☐	☐	☐
4. How much effort did you put into trying to influence decisions?	☐	☐	☐
5. How effective were you in influencing decisions?	☐	☐	☐
6. How well did you listen to others?	☐	☐	☐
7. How sensitive and supportive were you to others' feelings and ideas?	☐	☐	☐
8. Overall, how satisfied were you with your contribution to this activity?	☐	☐	☐

Look back over your ratings on this sheet and place check marks beside two areas in which you could improve. In the space below, set targets or reminders which could help you to improve.

____

____

____

____

Sample Group Self-Rating Scale

Place an X on each scale to indicate how this group would be rated for the task just completed.

Clear task and sequence of activities	____	____	____	____	Confused. No idea of what to do
Extremely trusting and open with each other	____	____	____	____	No trust. A closed group
Extremely sensitive and supportive to each other	____	____	____	____	No awareness or concern for others
All members took part effectively	____	____	____	____	Only one or two contributed
Disagreements welcomed and explored	____	____	____	____	Disagreements avoided or repressed
Decisions made by consensus	____	____	____	____	No decisions reached at all
Leadership strong, flexible and shared	____	____	____	____	No leadership – drifted

Enhancing and Evaluating Oral Communication in Secondary Grades, British Columbia Ministry of Education, 1988.

Student Report

The student report allows students to look back and reflect on the process involved in scientific inquiry. It focuses the students' attention on the thinking required to work through an investigation, assignment or project. Some questions that could be answered in such a report are:

- What did you do when you first saw the assignment?
  What were your thoughts?
- Did you use any science inquiry strategies? Which ones?
  How did they work?
- Did you have to change approaches to complete the assignment?
- Did you complete the assignment?
  How do you feel about this?

- Did you check your work in any way to assure the original assignment was carried out correctly?

Inventories

An inventory is a list of items students selectively choose to give an organized self-appraisal of performance or attitudes. Inventories have the advantage of allowing students' input into the evaluation process, while requiring very little of the teacher's time for collection of evaluation data. The accuracy depends on the quality of insight students have into their performance or attitude. Such inventories can be misinterpreted or the students may not be candid. It is easy to assume unwarranted reliability. Thus, it is recommended that inventories be used only in conjunction with other evaluation techniques, such as teacher observations and tests.

An inventory is a list of items students selectively choose to give an organized self-appraisal of performance or attitudes.

The most common form of inventory is an *Attitude Inventory*. A sample of an attitude toward science inventory, developed for Alberta Education in 1978, has been included in the Appendix (pp. 30–34) with details for administration and scoring. It is meant to be administered before the course begins and after the course is completed. Such as survey is not meant to determine individual attitudes but to look at the class results as a whole to determine if significant difference in attitudes has occurred during the course duration.

The most common form of inventory is an Attitude Inventory.

Modified attitude inventories, where students are encouraged to write freely about their feelings toward various activities within a particular unit, can be drawn up and administered at the end of each unit. These instruments can start off assessing students 'attitudes but gradually work into encouraging discussion of some major concepts within those units, requiring application of some specific skills.

A *Personal Performance Inventory*, that requires the students to rate their performance in class on a regular basis, can be helpful. It can serve to focus their attention on desired behaviours through a process of self-assessment. The teacher can compare the student self-assessment with their rating of student performance in any given period. An example of a simple inventory follows.

A Personal Performance Inventory, that requires the students to rate their performance in class on a regular basis, can be helpful.

Sample Personal Inventory

Instructions: Check the appropriate item if "yes"; leave blank if "no."

_____1. Arrived on time with required supplies

_____2. Copied any required notes and filled handouts in appropriate section of notebook

_____3. Listened attentively to instructions for the daily activity, asking for clarification if not understood

_____4. Became involved in class discussion by actively participating and/or following the discussion closely

_____5. Got to work on the activity quickly and stayed with it until completed

_____6. Worked cooperatively with other group member(s) and contributed my share of effort in completing the activity

_____7. Completed all assigned questions in class

_____8. When finished the assigned activity, an enrichment activity was chosen and worked on for remaining time

Holistic Scoring and Performance Assessment

Holistic scoring is a quick and efficient method of subjectively assessing students' problem-solving skills, participation, or the products associated with various activities and assignments. Different types of holistic scoring are possible, some with several categories of criteria for awarding marks, others short and simple. The more specific the criteria, the more objective this type of subjective scoring can become. The type of holistic scoring used depends on the purpose of your evaluation.

All-or-none scoring can be useful when evaluating a student's effort as acceptable or not acceptable.

All-or-none scoring can be useful when evaluating a student's effort as acceptable or not acceptable, allocating a small number of marks if acceptable, and none if not. This type of scoring is efficient for quickly checking if assignments are done, problems are attempted, or other tasks are completed. Students receive marks for effort, which encourages participation. All-or-none scoring should be limited to a small proportion of the course's total mark allocation, perhaps less than five percent.

Focused Holistic Scoring is useful for evaluation of science inquiry ability or participation.

Focused Holistic Scoring is useful for evaluation of science inquiry ability or participation. A science inquiry model, in the broad sense, can be applied to problem solving, decision making or many other activities or assignments a student may be required to do.

The products of such activities may be laboratory reports, perspective identification exercises, questions assigned on daily activities, oral presentations, models, paragraphs, some essays, and some library research papers, collages, scrapbooks, or a video production. All these items, as well as written response questions on formal tests, may be evaluated using Focused Holistic Scoring.

This method involves the establishing of categories on a scoring scale; in the example shown in the appendix, a 5–4–3–2 scale was chosen, with 0 for not done or handed in, and E for an excused student.

Using an even number of scoring categories can be useful (but not essential) as this helps prevent the tendency to assign marks to the middle category of the scale.

Evaluation Matrix: Focused Holistic Scoring

Activity / Score	Problem-Solving Skills	Participation	Product (e.g. Laboratory Report, Perspective Identification, Scrapbook)
5	Understands problem (investigation, issue, assignment) Selects necessary strategies Solves correctly (completes) Evaluates appropriateness of solution (conclusion, opinion, product)	Gets involved quickly Stays involved	Complete, Correct, Commands respect, Neatly done
4	As above but fails to evaluate solution (conclusion, opinion, product)	Needs a start Stays involved	Mostly complete Correct, neat Good work
3	Errors evident but strategies selected led to a solution (conclusion, opinion product)	Needs periodic reminders to stay on task	Somewhat complete Minor errors Satisfactory
2	Errors evident No solution provided (no conclusion, opinion, product)	Needs constant reminders to stay on task	Incomplete Major errors. Untidy
E	Acceptably Excused from the Assignment		
0	Not Done or Handed In		

Holistic scoring and performance assessment are related. **An assessment of performance should not mix analytical and holistic scoring to maintain its reliability.**

SCIENCE PRODUCT EVALUATION

Science product evaluation refers to determining the students' achievement after performing science processes or problem solving. Products of science activities or problem solving include a completed dissection, a focused specimen (or any laboratory "end point"), a written laboratory report, completed and submitted assignments, research projects, models or diagrams, essays, quizzes, tests and final examinations. These products can be evaluated by the teachers to determine student achievement. It is important that a variety of products of "doing science" are marked by the teacher.

1. Analytic Scoring

Analytic scoring assigns point values (scores) to each of several phases of the science inquiry process. First, an analytic scale is developed to identify those phases of the science inquiry process that you wish to evaluate. Next a range of possible scores for each phases is drawn up. The suggested range is zero to two.

This type of scoring could be applied to a large variety of written assignments such as laboratory reports, paragraphs, essays, short-answer questions, analysis of newspaper articles, or identification of perspectives on an issue. It enables the teacher to evaluate students' performance in relation to predetermined steps of the problem-solving process.

Analytic scales are useful when:

- it is desirable to give students feedback on their performance in key categories associated with science inquiry.
- it would be useful to have specific information about students' strengths and weaknesses
- the teacher is trying to identify specific aspects of problem solving that may require extra instruction
- the teacher has enough time to analyze carefully each student's written work.

Analytic scales can be applied to evaluate a written ***laboratory report*** using each of the six phases involved in problem solving, previously referred to on pages 11 and 12. The example presented below uses a five-point analytic scale.

The ***research project*** may be used to gather and analyze information and/or data concerning a current issue (e.g., environmental, technological) which may eventually lead to making decisions. The field work which accompanies this research uses the science inquiry and/or problem-solving models to provide the data obtained from experimentation.

One model for the steps involved in developing the research project follows:

- Planning
  - establish topic
  - identify information sources
  - establish evaluation criteria
  - review process
- Collecting Information
  - locate resources
  - collect resources
  - review process
- Processing Information
  - choose relevant information
  - evaluate information
  - organize and record information
  - create product
  - review and edit
  - review process
- Information Sharing and Explaining
  - present findings
  - demonstrate appropriate audience behaviour
  - review process
- Evaluating
  - evaluate product using analytic scales previously presented on pages 22 and 23
  - evaluate research procedures
  - review process

The ***library assignment*** focuses on a specific and localized aspect of science research; for example, describing the nature and function of technological devices, or providing background information about environmental issues.

A sample library assignment is provided in Appendix 2, page 48.

Case studies of actual scientific inquiry or problem-solving situations can be used to stimulate interest in science as well as develop the deductive abilities of the students. The case study is a narrative of the events leading up to an important scientific discovery. The purpose of the case study is to sharpen analytical and deductive processes by asking questions about that background of the discovery and analyzing the discovery, using the science inquiry sequence of data base → hypothesis → prediction → experiment → verification of the prediction.

A sample case study activity is provided in Appendix 3, pages 49–51.

2. **Quizzes, Tests and Examinations**

These are the most common and familiar examples of the products of "doing science". It is necessary to discuss both the construction and the marking strategies involved with these instruments.

The respective Program of Studies should always guide the construction of any quiz, test or examination. The objectives of the program of studies provide the purpose for evaluation and therefore the purpose for the questions asked. It is correct to say, then, that a question that is in accordance with the course of studies is valid.

If the difficulty level of a question is suitable and if the students have had appropriate instruction then the question can be categorized as reliable. It is important to note other factors affect reliability of questions. If the question is multiple choice, then the distracters must all seem plausible to the student; should all be the same length, different lengths or follow a 2 (long), 2 (short) variation; and should not use vocabulary unfamiliar to the students.

If the difficulty level of a question is suitable and if the students have had appropriate instruction then the question can be categorized as reliable. It is important to note other factors affect reliability of questions. If the question is multiple choice, then the distracters must all seem plausible to the student; should all be the same length, different lengths or follow a 2 (long), 2 (short) variation; and should not use vocabulary unfamiliar to the students.

The following are suggested, not definitive, guidelines for placing questions into categories according to cognitive level.

Knowledge/Comprehension (K/C)

- knowledge of themes, concepts and skills
- comprehension and understanding of themes, concepts and skills

Application (A)

- concepts and skills related to themes and previous learning
- application of themes, concepts and skills to new situations
- application of themes, concepts and skills within an STS context

Higher Mental Activity (HMA)

- synthesis, problem solving, critical thinking, linking, etc., within a theme, concept, skill or STS context
- comprehensive questions linking to other units

The purposes of an examination, test or quiz is to assess all learner expectations in an appropriate balance. To assure balance of coverage and thus the validity of the examination, test or quiz, an exam "blue-print process" is recommended. A sample blueprint for a Science 10 year-end examination is provided below.

UNIT	LEARNING DOMAIN	COGNITIVE LEVEL			WRITTEN RESPONSE	
	Themes/Concepts/ Skills/STS	K/C	A	HMA	# Questions	Mark
1 (20%)	12	1 or 2	8	1 or 2	1	12
2 (20%)	12	2 or 1	8	2 or 3	1	12
3 (20%)	12	1 or 2	8	3 or 2	1	12
4 (20%)	12	2 or 1	8	2 or 3	1	12
Comprehensive Questions (20%)	12	1 or 2	8	3 or 2	1	12
100%	60	8	40	12	5	60
	50%				50%	

The questions on *quizzes* could be short answer, short paragraph, multiple choice, diagram labelling or problem solving. As quizzes have a role in formative evaluation they can be made primarily of K/C type questions with a few A and HMA questions.

Unit tests, midterm, and final examinations could be made of multiple choice and extended response questions.

Example: 30 multiple choice (1 mark each)
2–3 extended response (10–12 marks each)
Time: 1 hour

The majority of these questions (65–70%) should be A with a few K/C and HMA. The extended response questions should integrate the themes of the unit and/or units if this is the final examination.

Exemplary unit tests and final examinations have been constructed by teachers from across Alberta. These are currently available for Science 10 and will be available for Science 20, Biology 20, Chemistry 20, and Physics 20. The Learning Resources Distributing Centre will be carrying hard copy, ASCII format disks, and LXR-test disks of these assessment resources.

A clear and definite idea of the required answers and their weightings should be available prior to the administration of the quiz, test or examination. The weightings per question should be made known to the students very explicitly.

A clear and definite idea of the required answers and their weightings should be available prior to the administration of the quiz, test or examination.

Example: This question will be scored out of four since there are eight points to be made. (eight 1/2 marks = 4 marks)

The answer key should be made available to the students after the quiz, test or examination is marked, and there should be discussion and test review.

3. Science Portfolios

Science portfolios are collections of documents produced and chosen by students to enrich the assessment and evaluation of their individual achievement within a science course. These collections can be used to plot the successes of students over the duration of a course as well as provide the base in formative evaluations at various time intervals. Portfolios may also be used as part of the summative evaluation where students choose the documents to be included.

These collections can be used to plot the successes of students over the duration of a course as well as provide the base in formative evaluations at various time intervals.

Although teachers of other subjects (e.g., art, language arts) have always kept folders of student work, science teachers have not usually kept this type of record. Portfolios may now have more focus in science courses and be more important for assessment purposes as the measurement of learning outcomes takes into consideration more of the diagnostic nature of formative evaluation.

Teachers should look at many portfolios before trying to establish a standard of assessment. The detailed description of assessment standards (rubrics) will vary with the instructional goals set for each situation.

Some examples of materials produced by students to include in a portfolio are:

- written descriptions of the results of science inquiry and problem-solving descriptions
- extended analyses of problem situations and investigations that go beyond the assigned task
- descriptions and diagrams of science inquiry and problem-solving processes
- models representing the solving of technological problems
- graphical representations of experimental data
- reports of investigations of major science ideas (e.g., the relationship between prime energy and ecological systems)
- responses to written response questions and problems
- individual and group research reports and projects
- copies of school and community-based awards and prizes
- video-, audio-video and computer-generated examples of student work.

Student portfolios can provide:

- evidence of a different kind of performance beyond the time restraints of regular paper-and-pencil tests
- assessment records that reflect the emphases of a good science program
- a permanent and long-term record of student progress, reflecting the lifelong nature of learning
- a clear and understandable picture of student performance rather than a score number
- opportunities for improved student self-image as a result of showing accomplishment rather than deficiencies
- recognition of different learning styles making assessment less culture-dependent and less biased
- an active role for students in assessing and selecting their work.

A portfolio may also incorporate important information about *student attitudes* toward science, such as:

- a science biography, renewed each year
- a student self-report about objectives learned and/or yet to be learned
- a description of how the student feels about science
- the work chosen by the student
- excerpts from the student's science journal.

PLANNING FOR STUDENT ASSESSMENT AND EVALUATION

Student assessment and evaluation requires careful planning and the development of appropriate criteria. When planning for the assessment and evaluation of students in the high school science courses, the following suggestions may be helpful:

- A long-range plan for student assessment should be developed and communicated to students, parents and administrators early in the term.
- A general assessment of student attitudes toward science is encouraged with an attitude inventory administered before and after the course.
- Attitudes can be assessed after each unit, providing information facilitating improved teaching strategies.
- The thinking processes of students can be evaluated, as well as their conclusions, answers or products.
- It is desirable to conduct an early assessment, both formal and informal, of the level of student skill and concept development in relation to each unit of study.

It is desirable to conduct an early assessment, both formal and informal, of the level of student skill and concept development in relation to each unit of study.

There should be careful construction of all assessment and evaluation instruments used to evaluate the level of concepts, skill and attitudinal development within the context of the learner expectations of the program of studies.

- The teacher should develop and communicate to students a set of clear and concise criteria for activities that contribute to the assessment and evaluation of student achievement.

- A large variety o assessment and evaluation strategies should be used.
- Ideally, some type of formative and summative evaluation should occur every period.
- Workable rotation assessment schemes can be developed so that every student need not have every activity, every period, contribute to their evaluation.
- It is desirable to have assessment strategies (e.g., checklists) that can be quickly and easily applied while the students are involved in skill developing activities.
- Regular and systematic evaluation provides the student and teacher with information valuable in determining appropriate learning strategies.
- Consider supplementing the final unit and course examination with a broader range and number of assessments applied within each unit for inclusion in a student portfolio.
- Explore various combinations of open and closed notebook examinations.
- Consider having students generate questions with answers and evaluation criteria.

1. Course Evaluation Plan

This plan should indicate clearly the method used to evaluate students for report card and final grade purposes. A general statement explaining the contribution of each assessment strategy to the overall evaluation should be developed and communicated to the students and their guardians. It should include a variety of assessment strategies as shown in the following sample plan.

Science Course Evaluation Plan	
Student Portfolio	____%
Research Project	____%
Problem-Solving Skills (Holistic Scoring of On-Site Lab Performance)	10%
Selected Laboratory Reports (Analytical Scoring of Lab Report)	10%
Quizzes and Unit Exams	____%
Laboratory Station Exam	____%
Final Exam	____%

2. Unit Assessment and Evaluation Plan

The unit plan is a more detailed description of the assessment and evaluation breakdown for a particular unit. An outline of this plan should also be communicated to the students at the beginning of the unit. It should include a variety of strategies as shown in the following sample plan.

Science Unit Assessment and Evaluation Plan

<table>
<tr><td>Daily Activity Assessment</td><td colspan="3">Unit:</td></tr>
<tr><td>Skill Development (Assessment)
• science inquiry
• problem solving
• decision making</td><td>%</td><td rowspan="2">%</td><td rowspan="3"></td></tr>
<tr><td>Journal Writing (Assessment)
Mind Mapping</td><td>%</td></tr>
<tr><td>Activities and Participation
Portfolio (selected assignments)
(Assessment)</td><td colspan="2">%</td></tr>
<tr><td>Unit Project (Evaluation)
• research
• case study</td><td colspan="2"></td><td>%</td></tr>
<tr><td>Specific Unit
• concepts (Evaluation)
• skills (Assessment)</td><td colspan="2"></td><td>%</td></tr>
<tr><td>Unit Exam (Evaluation)</td><td colspan="2"></td><td>%</td></tr>
</table>

It is not intended that all these strategies become part of an individual unit assessment and evaluation plan; rather, a selection of different strategies throughout the course wouid give a balanced approach which would allow students with different learning styles and preferences the opportunity to achieve.

ATTITUDE INVENTORIES

1. Directions for Administering the School Subjects Attitude Scales

Directions to the student are available with the scales and are not reproduced here. It is necessary that HB pencils be used if answer sheets are to be machine-scored. Sufficient of these for the largest class will facilitate administration of the scale.

Because faking is possible, procedures should be adopted to reduce motivation for faking. These include the following: student anonymity (the student's name is not required on the answer sheet), no monitoring of responses by the teacher of the student in the subject being rated, and general explanations of the group nature of the results.

The person who administers the scale should be, to the student who is rating a subject, neutral with respect to the subject; e.g., a non-teaching principal or vice-principal, teacher of another subject, school psychologist, or the like. Monitoring should be restricted to ensuring that the rating is being done correctly. Names or other identifying data should not be prescribed for the response sheets. The person who collects the sheets should collect them face down, to avoid appearing to scrutinize responses. These suggestions for administration are all designed to reduce faking.

Students have seldom had experience with ratings. The first time the scales are administered to a class, the directions to the student should be read with the students, and illustrated. Then the person administering the instrument should start the students on the scales with the "nice–awful" bipolar pair and illustrate how the rating of this pair should be made. The administrator should then indicate that the rest of the bipolar pairs are completed for the same subject in the same way.

Depending on the time required for students to grasp the task, the first administration of the scale may take ten to twenty minutes. With experience, students can usually rate a school subject in five minutes.

Because attitudes toward school subjects may be coloured by general attitudes (feeling tired or bored), for comparative uses it is suggested that the scale be administered during the second period of the school day.

2. Scoring

Each response has a possible value ranging from 1, representing the most negative attitude, to 5, representing the most positive feeling. The items and score values for each response position are shown on the next page. Since each of the three scales, evaluation, usefulness and difficulty, contains five adjective pairs, the score range for each scale is 8 to 40. A score of 24 on a scale represents a completely neutral score. Any score above 24 indicates a general positive feeling toward a subject, and similarly, any score below 24 represents a negative feeling. It will be observed that a positive attitude on the evaluative scale (nice, interesting, pleasant, like, bright, alive, lively, exciting) was signified by a positive score. Usefulness (useful, important, practical, valuable, helpful, necessary, advantageous, meaningful) was signified by a positive score. Difficulty (hard, heavy, confusing, complicated, advanced, strange, puzzling, rigorous) was associated with a negative score; that is, the higher the score the easier the student found the subject to be. This is consistent with the decision to make higher scores associated with favourable attitudes.

3. Reliability and Validity

The reliability of the scales varies from scale to scale, subject to subject, and grade to grade. When used for classroom groups, the reliabilities are very nearly all well above 90. Calculations of a sample of the reliability estimates indicates that the Difficulty scale is slightly less reliable than the other scales.

On four different comparisons, the scales were found to be valid. The comparisons included expert opinion, student preferences, sex differences, and cultural differences. A study of the relationship with achievement and intelligence gave further evidence of validity, as did the factor analyses.

4. Interpretation of Results

Scores can also be interpreted in an absolute sense. Each scale consists of eight word pairs; therefore, the score range for each scale is 8 to 40. A "neutral" attitude corresponds to a score of 24. An evaluative score above 24 indicates that the subject is liked, a usefulness score above 24 indicates that the students find the subject useful, and a difficulty score above 24 indicates that the students find the subject easy. Similarly, scale scores below 24 indicate a dislike for the subject, that it is not useful, and that it is difficult.

Alberta
EDUCATION

SUBJECT	

SCHOOL	

Place only one mark between each pair of words.
Complete ALL of the pairs.

Sex   Female ☐   Male ☐

	very much	a bit	neither	a bit	very much	
nice	☐	☐	☐	☐	☐	awful
boring	☐	☐	☐	☐	☐	interesting
unpleasant	☐	☐	☐	☐	☐	pleasant
dislike	☐	☐	☐	☐	☐	like
bright	☐	☐	☐	☐	☐	dull
dead	☐	☐	☐	☐	☐	alive
lively	☐	☐	☐	☐	☐	listless (inactive, lazy)
exciting	☐	☐	☐	☐	☐	tiresome (makes a person feel tired)
useless	☐	☐	☐	☐	☐	useful
important	☐	☐	☐	☐	☐	unimportant
impractical	☐	☐	☐	☐	☐	practical
worthless	☐	☐	☐	☐	☐	valuable
helpful	☐	☐	☐	☐	☐	unhelpful
unnecessary	☐	☐	☐	☐	☐	necessary
harmful	☐	☐	☐	☐	☐	advantageous (brings good or gain)
meaningful	☐	☐	☐	☐	☐	meaningless (doesn't make sense)
hard	☐	☐	☐	☐	☐	easy
light	☐	☐	☐	☐	☐	heavy (a lot of work)
clear	☐	☐	☐	☐	☐	confusing (mixes a person up)
complicated	☐	☐	☐	☐	☐	simple
elementary	☐	☐	☐	☐	☐	advanced (beyond the beginning level)
strange	☐	☐	☐	☐	☐	familiar
understanding	☐	☐	☐	☐	☐	puzzling (hard to understand)
undemanding	☐	☐	☐	☐	☐	rigorous (has to be exactly right)

SCORING GUIDE

Evaluative

nice	5	4	3	2	1	awful
boring	1	2	3	4	5	interesting
unpleasant	1	2	3	4	5	pleasant
dislike	1	2	3	4	5	like
bright	5	4	3	2	1	dull
dead	1	2	3	4	5	alive
lively	5	4	3	2	1	listless (inactive, lazy)
exciting	5	4	3	2	1	tiresome (makes a person feel tired)

Usefulness

useless	1	4	3	4	5	useful
important	5	4	3	2	1	unimportant
impractical	1	2	3	4	5	practical
worthless	1	2	3	4	5	valuable
helpful	5	4	3	2	1	unhelpful
unnecessary	1	2	3	4	5	necessary
harmful	1	2	3	4	5	advantageous (brings good or gain)
meaningful	5	4	3	2	1	meaningless (doesn't make sense)

Difficulty

hard	1	2	3	4	5	easy
light	5	4	3	2	1	heavy (a lot of work)
clear	5	4	3	2	1	confusing (mixes a person up)
complicated	1	2	3	4	5	simple
elementary	5	4	3	2	1	advanced (beyond the beginning level)
strange	1	2	3	4	5	familiar
understanding	5	4	3	2	1	puzzling (hard to understand)
undemanding	5	4	3	2	1	rigorous (has to be exactly right)

Science Attitude Survey Synopsis

School: ____________________

Teacher: ____________________

Pupil	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Averages
Evaluative																					
Usefulness																					
Difficulty																					

Pupil	21	22	23	24	25																Averages
Evaluative																					
Usefulness																					
Difficulty																					

Class Average Results

Evaluative	=
Usefulness	=
Difficulty	=

LIBRARY ASSIGNMENT

Modern Technological Devices and Science

Briefly describe how any two of the following modern devices works. Specify what scientific principle had to be understood in order to develop the device. Discuss the advantages and disadvantages of the use of this technology.

List: Telephone, Light, Microscope, Ultrasound Technology, X-ray, Lasers, or technology of your choice.

Your mark for this exercise will be based on the accuracy and clarity of the information reported and the understanding of the science and technology involved.

The weighting of marks for this assignment will be as follows: There will be 10 marks for the ***Science and Technology*** component of the assignment and a further 5 marks for the ***Communication Skills*** component for a total of 15 marks on the assignment. The marks will be assigned in accordance with the following scales:

Science and Technology	Communication (Oral and Written) Skills
The work displays an understanding of the technology and the science associated with that technology.	The work is effective in creating an impression that demonstrates control of diction, syntax, mechanics and grammar.
5 Technology and science are correct, relation between them is made explicit, and an understanding of the need for this technology is understood.	5 Writing is skilfully structured and fluent so that the meaning is clear. Diction is appropriate, syntax controlled and relatively absent of errors.
4 Either the technology or the science (but not both) is misrepresented or misunderstood.	4 Writing is clear and generally fluent. Diction is appropriate and syntax is controlled. Minor errors do not reduce the clarity of communication
3 Neither the technology nor science are clearly presented.	3 Writing is clear. Diction adequate, syntax generally straightforward but awkward, and errors reduce but seldom impede communication.
2 The science presented is not related to the technology; or the science and technology presented are not associated with each other.	2 Writing is unclear or ineffective. Meaning must be supplied by the reader. Diction inappropriate, syntax awkward and errors impede communication
1 Misunderstanding of the science and the technology that are presented is evident.	1 Writing frequently not fluent. Diction inaccurate, syntax uncontrolled, and errors severely impede communication.

CASE STUDY

Airplane Crashes and Birds

Read the following passage first for interest, then review the questions contained in the background data base and analysis section. Answer the questions in both these sections by an in-depth study of the passage. Use the knowledge gained by your study to complete the following task.

Think of a way to discourage birds from flocking to an airport. Gather background data, formulate an hypothesis, state a prediction and design an experiment to test the prediction. Indicate what you would consider to be a conclusion that would support the prediction and strengthen confidence in the hypothesis.

The big airplane had almost completed its flight. The passengers had finished their meals and the flight attendants had collected the trays. A final announcement had asked the passengers to make sure that their seatbelts were fastened and their chair backs were in the upright position. It was a routine landing in every way.

Suddenly, it wasn't routine any longer. The airliner ran into a flock of starlings. Birds were sucked into the engines and power was lost. The airplane plummeted to the ground. Sixty-two people were killed. It happened in October 1960, at Boston's Logan International Airport. The plane was a Lockheed Electra.

Birds are a major hazard to airplanes, particularly on takeoff and landing. They are not scared away by the thunderous din of a takeoff. Indeed, airports often seem very attractive places for birds to feed and rest. Runways can be especially attractive in wet weather. Worms come up out of the grass and crawl on the runways—a veritable feast for birds. many airports around the world suffer from this problem, and crews have to be sent out to sweep up the worms before they attract great flocks of birds.

Often the runways themselves seem to attract some bird species, like gulls. One group of biologists had the idea that it was the warmth of the black tarmac that was attracting the gulls. Near the airfield, they set up electrically heated pads. The pads, they hoped, would attract the birds away from the runways. The result was a complete failure. The gulls stayed on the runways. They completely ignored the specially-provided pads.

Another idea was to display dead birds in uncomfortable-looking positions near where flocks of the same species usually appear. Dutch biologists tried this technique at Amsterdam's busy Schiphol Airport. Again, the main problem was with gulls, and the decoys were gulls too. The hope was that the stuffed decoys would be seen by the live birds as a danger sign. The birds would then choose somewhere else to go.

When the birds were set up around the airport, the technique worked. The gulls saw them and flew away. Unfortunately, the stuffed birds soon became soaked with rain and had to be replaced. Worse, the gulls seemed to get used to them, and in a few weeks just as many were coming to the airport. Even as the experiment was being carried out, its effect on the birds was changing.

Moving the stuffed gulls from one place to another at the airport helped, but again, only for a while. It was too expensive to keep moving and replacing the stuffed birds, and not particularly effective.

A similar attempt, at New Zealand's Wellington Airport, was more successful. Some people might have thought that the Dutch experience would make the experiment useless, but the New Zealand biologists thought differently. They were dealing with a different kind of gull, the black-headed gull. The problem was a severe one, because large flocks of these gulls roosted at the airport all at once. This had been their habit in this particular oceanside location even before the airport was built.

The experiment worked. The birds went away, and as long as the stuffed gulls were in good condition, they stayed away. Perhaps, thought the biologists, models of dead gulls might work too. They had some plastic models made and installed at the airport. It turned out that the plastic models kept the gulls away just as well as the dead birds did. Two traditional black-headed gull roosts were eliminated for good.

The situation, though, was now rather puzzling. The same procedure that didn't work in Amsterdam did work in Wellington. The biologists weren't happy with this contradiction. There must be a reason for it, they thought. One possibility was that suitable roosting sites were available for gulls quite close to Wellington Airport. And indeed, when the same thing was tried at Whangarei Airport, in the far north of New Zealand, the results were far less impressive. At Whangarei, the airport is very close to the ocean, and the best nesting sites other than the airport are flooded at high tide.

An enormous number of experiments like this have been done, and all kinds of ingenious ways have been tried to discourage birds from coming to airports. Firing shellcrackers (shells with firecrackers in them), playing recordings of bird distress calls, flying trained hawks or falcons over them, or even model airplanes constructed to look like predator birds: all these techniques have been tried. None of them works with all bird species, and birds have an annoying habit of getting used to whatever is being used to frighten them off. And these procedures can be very expensive.

Other important ways of discouraging birds include filling in ditches where they like to bathe and drink, closing down nearby garbage dumps where they feed, and making sure that the grass on the airfield is of the correct length. Even the best grass length, though, seems to depend on the species of bird and the airport's location. At Montreal's Dorval Airport, for example, birds avoid grass longer than 15 cm. But at Toronto International Airport, the birds prefer the longer grass.

There seems to be no easy answers. Biologists and airport managers would like nothing better than to find a simple way of scaring away all birds at all times. Unfortunately, nothing of the kind exists. If a particular species of bird is a problem at a particular airport, then its habits must be studied along with everything that affects the birds: climate, nearby features attractive to birds, food availability, predators, and a host of other factors.

Yet this work is being done. Each year, the amount of damage done by birds to aircraft is being reduced. Although there are no easy answers, people working in the field are confident that they can learn more about the birds, and about how to reduce to a minimum the problems they pose to the humans who now share the air with them.

Adapted from *Science: Process and Discovery* by Dennis Field, Addison-Wesley Publishers, 1985.

Questions

1. Why do birds find airports attractive?

2. What method was tried to scare gulls away from Schiphol Airport in the Netherlands?

3. State two reasons why this method was not particularly effective after awhile.

4. Why was the bird problem particularly sever at Wellington Airport, New Zealand?

5. What differences were there between the method used at Wellington to deal with the problem, and the method used at Schiphol?

6. Name four other methods of scaring birds away from airports.

7. Name three general problems with the four methods you described in question 6.

8. Name three methods of discouraging birds form staying around airports which do not involve scaring them away.

Analysis

Questions 1–5 refer to the idea of setting up electrically-heated pads to attract birds away from airport runways.

1. What *experiment* did the biologists do?

2. What was their *prediction* about the results of the experiment?

3. Upon what *hypothesis* was the prediction based?

4. From what *data base* did the hypothesis arise?

5. As a result of the experimental findings, how did the biologists' view of the *hypothesis* change?

6. At Schiphol Airport, near Amsterdam, biologists displayed dead gulls in uncomfortable positions. What *prediction* did they hope would turn out to be true about the result of this *experiment*?

7. What was the *hypothesis* upon which the Dutch biologists based their prediction?

8. How did the *experiment* actually turn out?

9. At Wellington Airport, in New Zealand, the same type of *experiment* was more successful. What was the difference in the result? Why might the difference have arisen?

10. What *hypothesis* could be set out to explain the results of the experiments at Schiphol, Wellington and Whangarei?

SENIOR HIGH SCIENCE RESOURCES

by Desiree Hackman and Pamela Shipstone

The resources listed in this *Senior High Science Teacher Resource Manual* may be useful for implementing more than one of the new senior high science courses. The resources are categorized as follows:

- Basic Learning Resources
- Authorized Teaching Resources
- Support Learning Resources
- Other Resources
  - Videodiscs
  - Software
  - Laboratory Interfaces
  - Teacher Background
  - Print and Non-Print Resources

Basic learning resources are those student learning resources authorized by Alberta Education as the most appropriate for addressing the majority of learner expectations of course(s), substantial components of course(s), or the most appropriate for meeting general learner expectations across two or more grade levels, subject areas, or programs as outlined in provincial Programs of Study. These may include any resource format, such as print, computer software, manipulatives or video.
E.g., *Visions 1*

Authorized teaching resources are those teaching resources produced externally to Alberta Education by, for example, publishers, that have been reviewed by Alberta Education, found to meet the criteria of review and to be the best available resources to support the implementation of Programs of Study and Courses, and the attainment of the goals of education; they have been authorized by the Minister. Teaching resources produced as service documents by Alberta Education, such as teacher resource manuals (TRMs), diagnostic programs and monographs, are authorized by definition.
E.g., *Climates of Canada*

Support learning resources are those student learning resources authorized by Alberta Education to assist in addressing some of the learner expectations of course(s) or components of course(s); or assist in meeting the learner expectations across two or more grade levels, subject areas, or programs as outlined in the provincial Programs of Study.
E.g., *Perspectives in Science Series*

Other learning resources are those learning resources identified by Alberta Education as useful for teachers in the implementation of a course(s) or Program(s) of Study, but which have not undergone review procedures in Alberta Education. Alberta Education does not accept responsibility for use of these resources with students. It is the responsibility of the teacher to determine the suitability and application of these resources.

When searching for resources to support the new science program you may want to check:

1. Other departments within your school. Often resources are useful for ideas in more than one subject area. For example, Junior High Science, Environmental and Outdoor Education (EOE), Social Studies, Career and Life Management (CALM), or English.

2. School library for print or non-print resources

3. The regional resource centre or urban media centre for non-print resources (some authorized)

4. ACCESS for many authorized teaching and support video resources

5. LRDC for most authorized teaching and support print resources and some non-print resources

6. Government or non-government agencies for print and non-print educational materials or background information

7. Distributor for print and non-print resources

The basic resource will be available through the Learning Resources Distributing Centre (LRDC). A buyer's guide is available from the LRDC at the following address:

Learning Resources Distributing Centre
12360 – 142 Street
Edmonton, Alberta
T5L 4X9
Phone (403) 427-2767

Note: The information included in this listing was the most recent information available at the time the Teacher Resource Manual was prepared.

***Annotations preceded by an asterisk have been supplied by the distributor.**

Basic Learning Resources

SCIENCE 10

Visions 1

Format	Text
Annotation	Customized student resource for Science 10.
Price	$52.45
Author	Gage Educational Publishers
Distributor	LRDC 0SC10130

SCIENCE 20

Visions 2

Format	Text
Annotation	Customized student resource for Science 20.
Price	Not available
Author	Gage Educational Publishers
Distributor	LRDC

SCIENCE 30

Visions 3

Format	Text
Annotation	Customized student resource for Science 30.
Price	Not available
Author	Gage Educational Publishers
Distributor	LRDC

BIOLOGY 20–30

Biology Directions

Format	Text
Price	$54.44 (tentative)
Author	Don Galbraith
Distributor	John Wiley & Sons (Will be available at LRDC)

Nelson Biology

Format	Text
Price	$49.95 (tentative)
Author	Bob Ritter and Bruce Drysdale
Distributor	Nelson Canada (Will be available at LRDC)

CHEMISTRY 20–30

Addison-Wesley Chemistry

Format	Text
Price	$56.41 (tentative)
Author	Anthony C. Wilbraham, et al.
Distributor	Addison-Wesley (Will be available at LRDC)

Nelson Chemistry

Format	Text
Price	$49.95 (tentative)
Author	STSC Project
Distributor	Nelson Canada (Will be available at LRDC)

PHYSICS 20–30

Fundamentals of Physics: An Introductory Course

Format	Text
Price	$45 (tentative)
Author	David A. Martindale, et al.
Distributor	D.C. Heath (Will be available at LRDC)

Physics Principles and Problems

Format	Text
Price	$42 (tentative)
Author	Paul W. Zitzewitz, Mark Davids, and Robert F. Neff
Distributor	Maxwell, MacMillan (Will be available at LRDC)

Authorized Teaching Resources

Aquatic Invertebrate Monitoring Program

Format	Kit
Annotation	The kit includes a teachers manual and video. The video discusses Project AIM, methods and techniques and aquatic invertebrates.
Price	$85. Components can be purchased separately.
Distributor	FEESA

Climates of Canada (1990)

Format	Print	ISBN 0-660-13459-4
Annotation	This 176-page document is a valuable resource for the study of Canadian climate and environmental issues related to climate. The document includes descriptions of the climate of each province and territory, the factors that shape and control Canada's climate, and the elements of climate, e.g., rain, snow, tornadoes and hurricanes.	
Price	$14	
Author	Environment Canada	
Distributor	LRDC	0SC10133

One-Minute Readings: Issues in Science, Technology and Society (1992)

Format	Print
Annotation	Contains readings and questions related to issues in science, technology and society. Applications of science are raising tough questions and are creating problems that cannot be answered. The book is intended to give students practice in making the kinds of decisions they will experience in life. Students need a knowledge of science to find not the right answers but the best possible answers.
Price	Student Book $10.50; Teacher Manual $7.90
Author	R. F. Brinkerhoff
Distributor	LRDC

Senior High Science Video Series Programs 1–5

Format	Video
Annotation	Program 1: Baking Better Science (BPN 302201) Program 2: Zapped (BPN 302202) Program 3: Teaching From the STS Approach: The Nature of Science (BPN 302203) Program 4: Teaching From the STS Approach: Science and Technology (BPN 302204) Program 5: Teaching From the STS Approach: The Social Context of Science and Technology (BPN 302205) Programs 2–5 are teacher inservice video programs and will be available on one tape. Programs 3–5 show teachers practising STS strategies and interview educators and students as to their opinions regarding these methods. The teachers involved were practising these strategies in their classrooms in the fall of 1990 – before implementation of most of the new programs, Science 14-24 being the exception.
Price	See ACCESS catalogue
Distributor	ACCESS

Support Learning Resources

The Athabasca: A Case Study: Senior High Science Video Series

Format	Video
Annotation	This program examines the impact that proposed pulp and paper mills would have on the ecology of the Athabasca River, with a focus on a variety of viewpoints. This program supports the proposed biology and science courses as well as the current Biology 20.
Price	See ACCESS catalogue
Distributor	ACCESS BPN 302207

Back to the Sun: Senior High Science Video Series

Format	Video
Annotation	This program examines the conversions of energy from one form to another, with a focus on renewable energy sources. This program supports Science 10 and the current Biology 20.
Price	See ACCESS catalogue
Distributor	ACCESS BPN 302208

Choosing Science: Senior High Science Video Series

Format	Video
Annotation	This program examines the careers of four people whose interests and training in various branches of science have brought them to the same place. – a research team at the University of Alberta. This program is directed to students in Grade 10 but it would be of interest to all senior high science students.
Price	See ACCESS catalogue
Distributor	ACCESS BPN 302209

Moving Mountains: Senior High Science Video Series

Format	Video
Annotation	The theory of Plate Tectonics is used to explain the formation of the Rocky Mountains, with a focus on how theories are formulated and how they predict and explain natural phenomena. This program supports the proposed Science 20 course, and will help some secondary science teachers to broaden their background in geology.
Price	See ACCESS catalogue
Distributor	ACCESS BPN 302206

Perspectives in Science Series

Format	Video (4 – 30-minute programs). The Program in Action; Biotechnology; Toxic Waste; Water
Annotation	Takes a major step toward the Science, Technology, and Society connection. Develops critical thinking about science and technology, examines basic application, and points out unforeseen problems or complications that often emerge as a consequence. Also available on laserdisc from Technovision. These videotapes contain docu-dramas with strong language and confrontation.
Price	See ACCESS catalogue
Distributor	ACCESS BPN 321901-321904

Other Resources

The information listed here was current when this Teacher Resource Manual was prepared. Teacher and student resources cited in "Other Resources" have potential to support courses outlined in the provincial programs of studies by enriching or reinforcing the learning experience. These resources are not authorized by Alberta Education. It is the responsibility of the teacher to determine their suitability and application.

VIDEODISCS

Videodiscs and multimedia libraries are distributed by companies in Canada. Some of these distributors are listed on pages S.6 – 50 to S.6 – 53.

BioSci II

Format: Videodisc

Annotation*:

- 2300 still photos, 100 film sequences with narration and 500 computer graphic diagrams in addition to the previous collection of 5000 visuals.
- Eight full dissections of the frog, fetal pig, earthworm, mussel, squid, crayfish, sea star and perch in labelled, unlabelled and quiz formats, and cat muscles.
- "Tour of the Cell"—a fantastic voyage around the organelles of a cell in 3D computer animation.
- Films of classic animal behaviour, continental drift, seasons, protein synthesis, physiology, and how to use a microscope.
- Comprehensive directory categorized by common name, scientific name, instructional concept and frame number. Each entry has a bar-code which can be read by the Pioneer Barcode Reader.

Price: $549 U.S.

Distributor: Videodiscovery

Cell Biology

Format: Videodisc

Annotation*: Explores the inner workings of the cell. Includes 86 film segments and hundreds of still frames covering: cell types, cell constituents, mitosis, cytokinesis, fission and cell mortality. Live action footage includes segments on animal cells, plant cells, budding, multiple fission, protoplasmic streaming, migration of organelles, migration of pigment granules, flagellar motility, and adaptation to passive displacement.

Price: $549 U.S.

Distributor: Videodiscovery

Chemistry at Work

Format | Videodisc

Annotation*

- More than 800 photos and 3D computer graphics demonstrate practical applications in chemistry—processes in human and natural environments, actual photos of historical scientific figures and equipment, and chemical materials.
- Approximately 30 short film/video segments, including the Hindenberg explosion, metallurgical processes and plant production of oxygen.
- Students can learn balancing equations along with other mathematical problem-solving skills necessary for understanding chemistry. Instructors no longer need to spend valuable class time assisting with this difficult material.
- Lab safety issues are covered, including handling acids, pouring, decanting, disposing of waste products and dealing with flammable materials.
- The Periodic Table database presents a picture of each element, followed by the one or more common substances in which it is found. A printed, barcoded Periodic Chart gives quick access to this database.
- The *User's Manual* identifies each image with barcodes and complete texts of the disc narrative.

Price | $549 U.S.

Distributor | Videodiscovery

Doing Che⁻ ·stry

Format | Videodisc

Annotation*

This product of the American Chemical Society contains 122 experiments and demonstrations. The activities, first developed in 1983 by chemistry teachers supported by UCLA, have been revised in this version based on feedback from workshops and reviews by safety experts.

The discs can be used to introduce the lab and show materials, equipment set-up, laboratory techniques and safety precautions. They may substitute for lab experiences for which time or equipment is not available. As a teacher training device, the series is invaluable since it presents time, materials, hints, hazards, disposal, introductory sets, question sets and answers, presentation questions, sample data, classroom copy masters, closure questions and practical applications.

Includes HyperCard software, a laboratory interfacing program for the Apple II, and a 600-page Teacher's Manual with complete instructions for each experiment and textbook cross-references. Most of the manual's contents were selected and designed by high school teachers.

Price | $549 U.S.

Distributor | Videodiscovery

Dream Machine I: The Visual Computer

Format	Videodisc
Annotation*	Explores the development of the computer as a visual instrument that combines the objectivity of photography, the subjectivity of painting, and the gravity-free motion of hand-drawn animation. The disc contains 112 computer-animated motion sequences.
Price	$48.70
Distributor	LRDC 0AR07009

Dream Machine II: Computer Dreams

Format	Videodisc
Annotation*	Celebrates state-of-the-art computer imaging, circa 1988. It looks at computer-aided design, architectural simulation, medical and biological simulations, flight simulation, space exploration, entertainment, and fine art.
Price	$48.70
Distributor	LRDC 0AR07010

Frog Anatomy and Physiology Library

Format	Videodisc
Annotation*	Featured on one videodisc, this program contains slides, diagrams, and movie clips which provide a detailed review of amphibian anatomy and physiology, and offers an alternative to dissection in the classroom. Included are more than 150 slides, 50 diagrams and 34 movie clips. Slides display detailed information about subjects such as embryology and metamorphosis, as well as major tissues, bones and muscles. Movie clips include studies of anatomy and physiology of all major organs and systems and show a variety of frogs in their natural habitat.
Price	Multimedia Library $595 U.S.; Frog Anatomy Discs only, $345 U.S.
Distributor	Optical Data Corporation

Garbage: The Movie – An Environmental Crisis

Format	Videodisc (24 min.)
Annotation*	A fascinating look at the problem of the environment and solid waste, as well as some promising solutions, presented in the vernacular of students. Our young host leads us to landfills and incinerators, to recycling plants and composting yards. Behind the scenes, we explore the reasons landfills are closing, discover how the garbage crisis is creating pollution, and search for the roots of the problem. We discover some hopeful solutions: recycling, reusing, reducing use, consumer choices and organized action.
Price	$470
Distributor	McIntyre Media Limited

Geology and Meteorology

Format	Videodisc
Annotation*	Contained on one videodisc, this program provides more than 7200 slides, a 400-term glossary and 34 movie clips for a thorough review of earth geology. The slide collection includes plate tectonics, volcanic formation and the many ongoing weathering processes affecting the earth. Movie clips examine volcanoes, including Vesuvius and Heimaey Island; tectonics, including the dynamics of continents and evolution of North America; meteorology, including rain and cloud droplets, thunderstorms, hurricanes and tornadoes; weathering, including glacial melting, erosion and cratering; and rocks and minerals, including composition, formation and lunar rock samples.
Price	Multimedia Library $995 U.S.; Discs only, $595 U.S.
Distributor	Optical Data Corporation

Global Warming: Hot Times Ahead

Format	Videodisc (23 min.)
Annotation*	Engaging, offbeat young Marc Price (from television's Family Ties) leads the way through this exploration of the Global Warming phenomenon and some of the devastating changes that may result. We learn about greenhouse gases and how they are produced by human activities, chiefly the burning of fossil fuels. The film illustrates how we can slow the build-up of greenhouse gases in the short term by conserving and using gases efficiently; how in the long term, we must develop new ways to use the sun's energy.
Price	$470
Distributor	McIntyre Media Limited

The Living Textbook: Principles of Biology/Life Science

Format	Multimedia/videodisc
Annotation*	A two-videodisc set, this program contains more than 2700 slides, 150 diagrams and 163 movie clips covering molecular, cell, plant, animal and human biology. Included are a 650-term glossary and 1000 of Oxford Scientific's best photos. Movie clips cover detailed biological processes such as: cell biology, from protein synthesis to living cells; reproduction, from spermatogenesis to frog development; human biology, covering a whole range of systems and their functions; protist biology; fungi, from bread mold to zoospore release; plant reproduction and life cycles; invertebrates; and vertebrate biology, including behaviour and interaction. Molecular, Cell and Human Biology (Sides 1 and 2) has curricular fit to Science 10–20–30 and Biology 20–30. Plant and Animal Biology (Sides 3 and 4) offer a comprehensive survey of life science. Sides 3 and 4 do not have direct curricular fit to the new senior high science programs but they could be used for reference or extension activities.
Price	Multimedia Library includes two videodiscs, print directory, barcoded lesson plans, interactive software for Apple IIGS and Macintosh computers and interface cable – $1495; Principles of Biology, Videodiscs only $995 for 2 or $595 each.
Distributor	Optical Data Corporation

The Living Textbook: Principles of Physical Science

Format	Multimedia/videodiscs
Annotation	A two-videodisc set, this program provides more than 2500 slides, 300 diagrams, a 325-term visual glossary and 90 movie clips for a comprehensive survey of physical science. Movie clips cover the structure of matter, including atomic theory and radioactivity; states of matter, including solids, liquids and gases; the conservation of energy; mechanics, including Newton's and Kepler's laws with examples; wave motion; light and sound, including refraction, polarization and energy levels; electricity and magnetism, including an electrochemical cell, magnetization, electromagnetics and aurorae observations. Matter, Motion and Forces (sides 1 and 2) and Waves, Electricity and Magnetism (sides 3 and 4) offer a comprehensive survey of chemistry and physical science. Both videodiscs have curricular fit to Science 10–20–30, Chemistry 20–30 and Physics 20–30. The two videodiscs feature more than 2500 slides, a 325-term visual glossary and 90 movie clips.
Price	Multimedia Library includes two videodiscs, print directory, bar-coded lesson plans, interactive software for Apple IIGS and Macintosh computers and interface cable – $1495; Principles of Physical Science, Videodiscs only $995 for 2 or $595 each.
Distributor	Optical Data Corporation

Our Environment (1990)

Format	Videodisc
Annotation	Inspire environmental understanding at the junior and senior high school level with this amazing treasury of 6000 colour photos sequenced with explanatory captions, maps, diagrams and film segments. The disc, carefully organized to allow easy Level I use, includes: • The four spheres of air, water, land and organisms. • A focus on important environmental problems—such as acid rain, energy usage, climate change, desertification, wetlands loss, tropical deforestation, oil spills, nuclear power and weapons, soil erosion, solid waste, species extinction, asbestos and water pollution. • A Visual Glossary and Panorama illustrating over 700 environmental terms and surveying the globe with captioned photos.
Price	Videodisc – $395 U.S.; Teacher Manual – $30 U.S.; Student Manual – $15 U.S.; HyperCard Stacks – $70 U.S.
Distributor	Optilearn

Periodic Table and Periodicity: Chemistry Series

Format	Videodisc and Guide (23 min.)
Annotation	Grades 10–12. Each of the chemical elements has its own unique physical and chemical properties. The fact that there is a pattern to these properties led to the development of the periodic table, a remarkable way of organizing these patterns. Animation succinctly develops the relationship between the electronic structure of an atom and its properties, demonstrating clearly why there are families of elements and gradual changes in the properties of elements.
Price	$210
Distributor	Coronet

Perspectives in Science

Format	Videodisc
Annotation	Takes a major step toward the Science, Technology, and Society connection. Develops critical thinking about science and technology, examines basic application, and points out unforeseen problems or complications that often emerge as a consequence. Also available on laserdisc from Technovision. These videotapes contain docu-dramas with strong language and confrontation.
Price	$345
Distributor	Technovision

Physics and Automobile Collisions

Format	Videodisc
Annotation	Using the attention-grabbing footage of car collisions, this disc provides a graphic and entertaining way for students to study the principles of momentum, Newton's laws, and mechanical energy. Collisions are recorded in 11 chapters on the disc, while an audio track emphasizes key concepts during the motion. Students then analyze the action using freeze-frame control, and measure the screen to gather data. Appropriate for three levels of physics instruction: descriptive physics, the algebra/trigonometry course in college physics, and calculus-based engineering physics.
Price	$225 U.S.
Distributor	Videodiscovery

Physics of Sports

Format	Videodisc
Annotation	This detailed record of over 20 athletic events, filmed expressly for scientific analysis, provides visual data from which quantitative data may be collected by biomechanics, kinesiology and physics students. The videodisc is used to step through actions in 1/30 second intervals. Using a sheet of clear acetate over the image on the monitor, students can study each position and collect data on such physical principles as linear motion, projectiles, energy transformation, momentum, impulse and time. This is an ideal way to apply physics to real world problems. Includes a student handbook and a teacher's guide detailing how the disc may be used in a typical physics curriculum, directory of the images, formulae and step-by-step instructions.
Price	$549 U.S.
Distributor	Videodiscovery

Sightlines

Format	Videodisc	
Annotation	Authorized for Senior High Art.	
Price	$136.50 includes laserdisc, cover, mini-catalogue. Detailed $13.95. Both are SEICAG-eligible.	
Distributor	LRDC	Laserdisc 0AR07006; Detailed Catalogue 0AR07007

These resources are not authorized by Alberta Education. It is the responsibility of the teacher to determine their suitability and application.

SOFTWARE

Interactive Physics

Format	Macintosh Note: New version to be released in June 1992.
Annotation	Interactive Physics allows users to create experiments by drawing objects on a screen. It lets users adjust physical quantities (such as mass, friction, elasticity and gravity) to explore their effects on an experiment. Each physics interaction (set of exercises) consists of a series of activities which involve modifying and observing experiments. The results of the experiments are then analyzed both mathematically and conceptually. Because Interactive Physics visually simulates real experiments, it allows students to learn by exploring and hypothesizing. 1. Stability 2. Free-Fall in One Dimension 3. Relative Velocity and Acceleration 4. Newton's First Law 5. Newton's Laws: Mass and Acceleration 6. Mass and Weight 7. Uniform Circular Motion 8. Rotational Kinematics 9. Centre of Mass 10. Linear Momentum 11. Collisions on an Air Track 12. Two-Dimensional Collision 13. Elastic Potential Energy and the Work Done by a Spring 14. Elastic Potential Energy, Gravitational Potential Energy and The Work Done by a Spring 15. The Spring-Launched Ball 16. Power
Price	$249
Distributor	Contact your local software distributor.

LXR Test

Format	Macintosh
Annotation	Test-generating program. There are three versions of the program: Personal, Professional and Scoring Editions. The item banks from ADLC have been created on the Scoring Edition of LXR to take full advantage of its additional features; however, the item bank will also work with the Personal and Professional Editions. There are some 'challenges' associated with using the Personal edition, but this may not be a problem depending on your level of use.
Price	Personal – $599 U.S. (Site License) Professional – $799 U.S. (Site License) Scoring – $999 U.S. (Site License)
Distributor	Logic eXtension Resources

SimEarth

Format	IBM/Mac/Windows
Annotation	SimEarth is a planet simulator – a model of a planet. SimEarth is based on the Gaia theory by James Lovelock, which suggests that we look at our planet and the life on it as a whole and not as separate areas of study. SimEarth treats the planet as a whole: life, climate, the atmosphere, and the planet itself – from dirt and rock to the molten core – all affect each other.
Price	Check local software distributors
Distributor	Contact local software distributors.

These resources are not authorized by Alberta Education. It is the responsibility of the teacher to determine their suitability and application.

LABORATORY INTERFACES

Champ II

Format	IBM PC and PS/2 (Mac version will be released later this year)
Annotation	Champ II allows you to perform/analyze experiments using probes, software and computer hardware.
Price	Contact Merlan Scientific for price list.
Distributor	Merlan Scientific

Leap

Format	IBM/IBM Compatible/Apple II/Mac
Annotation	Leap allows you to perform/analyze experiments using probes, software and computer hardware. Interdisciplinary Lab Pac (Physics/Chemistry) and Biology and Principles of Technology (Applied Physics) Lab Pac are available. Lab Pacs include manuals, interface card, software and several probes/cables.
Price	Contact Quantum Technology for price list.
Distributor	Quantum Technology, Inc.

Personal Science Lab

Format	IBM/Compatible
Annotation	PSL allows you to perform/analyze experiments using probes, software and computer hardware.
Price	Contact local distributors for price list.
Distributor	Computerland

These resources are not authorized by Alberta Education. It is the responsibility of the teacher to determine their suitability and application.

TEACHER BACKGROUND

Chemistry, Third Edition (1988)

Format	Print	ISBN 0-07-555235-3
Annotation	Written at an introduction college level, this text gives a thorough treatment of basic chemistry concepts. In addition, the "Chemistry in Action" sections show the relevance of chemistry to medical, biological, and engineering fields.	
Price	$44.84 U.S.	
Author	Raymond Chang	
Distributor	McGraw-Hill	

Chemistry: A First Course (1987)

Format	Print	ISBN 0-201-17880-X
Annotation	This introductory high school chemistry text presents the basic concepts of chemistry in a clear and understandable manner, using numerous practical examples. The text examines some of the major social issues confronted by the Canadian chemical industry.	
Price	$34.20	
Author	Geoffrey Rayner-Canham & Arthur Last	
Distributor	Addison-Wesley	

Chemistry: A Second Course (1988)

Format	Print	ISBN 0-201-17885-0
Annotation	This text is written for a senior-level high school chemistry course. The relevance of chemistry is emphasized by examining some current environmental questions.	
Price	Information to follow	
Author	Geoffrey Rayner-Canham & Arthur Last	
Distributor	Addison-Wesley	

Conceptual Physics, Sixth Edition (1989)

Format	Print	ISBN 0-673-39847-1
Annotation	Physics is treated conceptually rather than mathematically in this text. The physics concepts are present in English and equations are used as guides for thinking, rather than recipes for algebraic problem solving.	
Price	$46.69	
Author	Paul G. Hewitt	
Distributor	Scott Foresman	

Fundamentals of Physics: A Senior Course (1986)

Format	Print	ISBN 0-669-95047-5
Annotation	This text is written for a senior-level high school physics course, and provides a thorough examination of basic physical concepts. It is an algebra-based physics text with many examples drawn from everyday life.	
Price	Information to follow	
Author	David G. Martindale, Robert W. Heath, & Philip C. Eastman.	
Distributor	D.C. Heath Canada Ltd.	

Heath Chemistry, Canadian Edition (1987)

Format	Print – Teacher's Edition Text	ISBN 0-669-95290-7 ISBN 0-669-95289-3
Annotation	This high school chemistry text focuses on student understanding of basic chemistry principles, with special emphasis on proportional reasoning in chemistry calculations	
Price	$64.95 Teacher's Edition $49.95 Text	
Author	J. Dudley Herron, et al.	
Distributor	D.C. Heath Canada Ltd.	

The Nature of Life (1989)

Format	Print	ISBN 0-07-557035-1

Annotation

This introductory college level text is clearly written and richly illustrated. The book is organized around three unifying themes:

- living things take in energy to maintain their internal order and organization;
- living things undergo reproduction so that the species continues after the individual ceases to exist; and
- living organisms are able to adapt to changing environments.

Price — $43.08 U.S.

Author — John H. Postlethwaite & Janet L. Hopson

Distributor — McGraw-Hill

Physics, Third Edition (1988)

Format	Print	ISBN 0-471-85221-X

Annotation

This text is written for introductory college level, with particular emphasis on applications of physics principles in the life sciences. It makes extensive use of examples involving biological and chemical systems and alternative energy sources.

Price — $59.95 U.S.

Author — Joseph W. Kane & Morton M. Sternheim

Distributor — John Wiley & Sons

Physics: Principles with Applications, Third Edition (1991)

Format	Print	ISBN 0-13-672510-4

Annotation

Written at an introductory college level, this text uses algebra and elementary trigonometry, but not calculus. The applications of physics concepts include a wide range of examples from biology, medicine, architecture, technology, Earth sciences, the environment and daily life.

Price — Information to follow

Author — Douglas C. Giancoli

Distributor — Prentice Hall Inc.

Understanding Biology, No. 2 (1991)

Format	Print ISBN 0-8016-2524-6
Annotation	Written at an introductory college level, this text is organized into three broad areas basic biological principles, ecology, and the structure and function of organisms. The first half of the text is devoted to principles shared by all organisms, and the second half is devoted to particular organisms, with an emphasis on vertebrate biology.
Price	$49.95 U.S.
Author	Peter H.Raven, & George B. Johnson
Distributor	Mosby Year Book

These resources are not authorized by Alberta Education. It is the responsibility of the teacher to determine their suitability and application.

PRINT AND NON-PRINT RESOURCES

Acidic Deposition: Water Literacy Series (1992)

Format	Print
Annotation	Includes background information and a series of activities related to acidic deposition. There are six modules in the package: What is Acidic Deposition? Sources of Acidic Deposition? Acid Sensitivity Effects of Acidic Deposition Sustainable Development Solutions
Price	Available free on request, Fall 1992.
Distributor	Alberta Environment

ACME School of Stuff – 13-Part Series

Format	Video
Annotation	Also authorized for Science 14-24.

Program 1
BPN 319001
Topics: cassette tapes, chocolate, and microwave ovens.

Program 2
BPN 319002
Topics: telephones, sewage treatment, and video.

Program 3
BPN 319003
Topics: batteries, water, and fuel injection.

Program 4
BPN 319004
Topics: records, neon and the cathode-ray tube.

Program 5
BPN 319005
Topics: light bulbs, the Canadian Standards Association, and modems.

Program 6
BPN 319006
Topics: electricity, glass bottles, and brakes.

Program 7
BPN 319007
Topics: the history, operation, manufacturing, and testing of the toilet.

Program 8
BPN 319008
Topics: cable television, the subway, and engineering.

Program 9
BPN 319009
Topics: traffic signals, a natural gas pipeline, and alternating current.

Program 10
BPN 319010
Topics: digital computers, folding paper cartons, and the electric shaver.

Program 11
BPN 319011
Topics: electronics, the body shop, and coin units in vending machines.

Program 12
BPN 319012
Topics: composite substances, piano rolls, and automobile alignment.

Program 13
BPN 319013
Topics: engines, wire, and satellites.

Price	See ACCESS catalogue
Distributor	ACCESS

AIDS: A Teacher Resource Package (1987)

Format: Print

Annotation: This resource is divided into eight lessons:

1. Introduction to AIDS
2. Biology of AIDS
3. Disease and Epidemics
4. Sex and Consequences
5. Decision Making
6. Death and Disease
7. AIDS and The Community
8. AIDS: The Future and the World

This Canadian publication offers a thorough explanation of the above topics. Each lesson includes information for teachers, blackline masters for student use, and answer keys for exercises. It also offers suggestions for further study, resource lists and test questions for evaluation purposes. (Authorized for CALM 20.)

Price	$19.95	
Author	J. H. Golick and James D. Grieg	
Distributor	LRDC	0LM11038

AIDS: What Every Responsible Canadian Should Know (1988)

Format: Print

Annotation: Not intended for student use. This publication offers a thorough explanation about AIDS through the following topics: testing, safe sex, government, women, parents and teachers, workplace, health care worker and the citizen. The information is presented in a question/answer format. It provides a quick reference for teachers and administrators. (Authorized for CALM 20.)

Price	$1.75	
Author	J. Greig	
Distributor	LRDC	0LM11020

Alberta Clean Air Act (1985)

Format	Print (pamphlet)
Annotation	Contains conclusions and recommendations of the review of the Clean Air Act – a report to the Minister of the Environment. (Authorized for Junior High Science.)
Price	Available free on request
Distributor	Environment Council of Alberta

Alberta Government Publications (1991)

Format	Print
Annotation	Includes a list of publications and periodicals organized by issuing government department or body, and then alphabetically by title.
Price	Available free on request
Distributor	Alberta Public Affairs Bureau

Alberta Wildflowers: Teachers Resource Kit (1989)

Format	Print
Annotation	Includes factsheets on topics such as how electricity is produced, coal in Alberta, history of coal in Canada, world coal resources, surface mining and more.
Price	Available free on request
Distributor	TransAlta Utilities

Asimov's Chronology of Science and Discovery (1989)

Format	Print ISBN 0-06-015612-0
Annotation	Describes the significant events of science. Illustrates how science and cultural, social and political events have affected each other.
Price	$29.95 U.S.
Author	Isaac Asimov
Distributor	Harper Collins

Atlas of Environmental Issues (1989)

Format	Print	ISBN 08-160-2023X
Annotation	Describes and explains major environmental issues of today's world including soil erosion, deforestation, mechanized agriculture, oil pollution of oceans, acid rain, overfishing, and nuclear power. Excellent graphics (Listed as support for EOE).	
Price	$16.95 U.S.	
Author	Nick Middleton	
Distributor	Facts on File	

Biotechnology, Selected Topics (1987)

Format	Print	
Annotation	The text outlines the role of biotechnology in industrial processes involving water treatment, food processing and marketing, health and disease (antibiotic production) and fuels. (Authorized for Junior High Science.)	
Price	$11.10	
Author	J. Teasdale	
Distributor	LRDC	0SC07052

Canada's Green Plan (1990)

Format	Print
Annotation	Discusses Canada's Green Plan for a healthy environment.
Price	Available free on request
Distributor	Environment Canada (Edmonton Office)

Canadian Environmental Education Catalogue: A Guide to Selected Resources and Materials (1991)

Format	Print
Annotation	Contains a comprehensive list of environmental education resources.
Price	$20 main volume; $40 2-year subscription (main volume plus supplementary volumes, 1 every 6–8 months)
Distributor	Pembina Institute

Canadian Petroleum Association Publications: Bibliography (April, 1991)

Format	Print	
Annotation	Includes a list of publications with annotations on topics such as: • Health and Safety • Offshore and Frontier • Research and the Environment • Acidic Deposition Research Program	
Price	Available free on request	
Distributor	Canadian Petroleum Association	

Clarification of Statements Prohibiting the Use of Human Body Substances in the Alberta Science Curriculum (1988)

Format	Print	
Price	$2.05	
Author	Curriculum Support, Alberta Education	
Distributor	LRDC	0XF00012

Clouds in a Glass of Beer: Simple Experiments in Atmospheric Physics (1987)

Format	Print	ISBN 0-471-62482-9
Annotation	Contains experiments for diffusion, heat transfer, conservation of energy, kinetic potential, solar radiation, the freezing point of water, cloud formations.	
Price	$12.95 U.S.	
Author	Craig F. Bohren	
Distributor	John Wiley and Sons, Inc.	

The Complete Handbook of Science Fair Projects (1991)

Format	Print	ISBN: 0-471-52729-7(c) – 0-471-52728-9(p)
Price	$18.50	
Author	Julianne Blair Bochinski	
Distributor	John Wiley and Sons, Inc.	

Conservation Strategy (1988)

Format: Print (pamphlets)

Annotation: Includes a series of discussion papers:

- Tourism in Alberta
- Agricultural Considerations for Today and Tomorrow
- Healthy Planet, Healthy People
- Oil and Gas in Alberta: An Uncertain Future
- Foundations for the Future: Alberta's Mineral Resources
- Energy Conservation: A Goal for Albertans
- Renewable Energy: The Power and the Potential
- Environment by Design
- Reserves for Nature
- A Place for Wildlife
- Environmental Education for a Sustainable Future
- Dinosaurs and Distant Drums
- Perspectives for an Alberta Conservation Strategy
- Resolving Conflict: A Case Study
- Alberta Conservation Strategy: Strategic Framework in Action
- Alberta Conservation Strategy: Strategic Framework in Brief
- Alberta Wetlands: Water in the Back
- Our Dynamic Forests: The Challenge of Management
- People, Parks and Preservation
- Electricity: Development for a Sustainable Future
- Saving the Strands of Life: Alberta's Biodiversity

Price: Available free on request

Author: Alberta Conservation Strategy Project

Distributor: Environment Council of Alberta

CRC Handbook of Hazardous Laboratory Chemicals: Information and Disposal (1991)

Format: Print ISBN: 084930265X

Annotation: Includes information about physical properties, fire hazard, chemical properties, hazardous reactions, physiological properties and health hazards, spillage disposal, waste disposal, and reactions for spillage and waste disposal.

Price: $95 U.S.

Author: M. A. Armour

Distributor: CRC Press

Critical Thinking: Day to Day (1988)

Format — Video (15 min)

Annotation — The junior high school debating team has been given the assignment of defining and demonstrating the process of critical thinking to the student body. They rehearse their presentation, taking examples from politics and advertising to demonstrate the framework for analyzing the information in the decision-making process. The students also learn not to spread information until all the facts have been obtained from a credible source.

Price — See ACCESS catalogue

Distributor — ACCESS VC286501

Current Living Series

Format — Print (factsheets)

Annotation — Includes factsheets on topics such as:

Compact Fluorescents in Your Home
Electric Ranges
Electric Frying Pan Buying Guide
Electric Deep Fat Fryers
Power Interruptions
Don't Blame the Appliance
Dishwashers
Cordless Power Tools
Convection Ovens
Coffee Machines
Clothes Washers
Clothes Dryers
Christmas Lighting
Central Vacuum Systems
Bread Maker Buying Guide
Blenders
Blanching Vegetables in Your Microwave
Bathroom Lighting
Artificial Lighting for House Plants
Appliance Operating Costs
Electric Yard and Garden Tools
Extension Cords
Food Dehydrators
Food Processors
Freezers
Hot Tubs and Spas
Indoor Electric Barbeques and Grills
Kitchen Lighting
Kitchen Machines
Landscape Lighting
Lifesaver Outlets
Microwave Jams and Jellies
Microwave Ovens
Outdoor Lighting for Security
Popcorn Makers
Portable Electric Heaters
Portable Toaster/Broiler Ovens
Refrigerators
Summer Cooking
Timers: Savings and Security
Whirlpools and Masseur Baths

Price — Available free on request

Distributor — TransAlta Utilities

Destination Conservation

Format	Print
Annotation	Destination Conservation is a program designed for delivery to Alberta school jurisdictions that seek to improve their energy, water and waste management practices. The manual consists of three sections: 1. The Program Begins Initial Awareness Activities Determining Energy and Resource Consumption Levels 2. Taking Action Energy Audit and Action Plan Conservation Campaign Resource Audit and Action Plan 3. Further Awareness and Action A Global Perspective Individuals Can Make a Difference Environmental Connections Overpopulation Energy and the Environment Transportation Global Warming/Greenhouse Effect Ozone Layer Depletion Deforestation Water Conservation Ecological Landscaping and Gardening Waste Management Cost Recovery Program for Paper Hazardous Materials
Price	$35
Distributor	Environmental Resource Centre

Ecology Studies of Lakes in Alberta: Water Literacy Series (1988)

Format	Print	
Annotation	Deals with the ecology of freshwater environments. Unit introduces human impact on lake environments and involves students in the methods and technology employed to study lakes. Workshops provided by Alberta Environment. (Authorized for EOE.)	
Price	$1.95 (free with workshop from Alberta Environment)	
Author	Alberta Environment	
Distributor	LRDC	0EV07024

Ecology Studies of Lakes in Alberta Teachers Package (1989)

Format	Print
Annotation	Deals with the ecology of freshwater environments. Unit introduces human impact on lake environments and involves students in the methods and technology employed to study lakes. Workshops provided by Alberta Environment. (Also authorized for EOE.) Includes Teachers Guide, Observation Notes, and Student Worksheets
Price	$16.20 (free with workshop from Alberta Environment)
Author	Alberta Environment
Distributor	LRDC 0EV07023

Education About AIDS: Education About AIDS for Secondary Teachers (1988)

Format	Video (29 min.)
Annotation	Teaching strategies are demonstrated, and available resources are highlighted for secondary teachers of AIDS education. To make use of this information, teachers are encouraged to find out about the level of AIDS awareness of students and then focus on aspects that need attention.
Price	See ACCESS catalogue
Distributor	ACCESS VC707502

Environmental Choice Program

Format	Print
Annotation	Includes information about: What is a good environmental choice? Who sets the criteria for certification? How are criteria set? How do you get involved in the public consultation? How do you apply for the Ecologo? Do all products have to comply? Are Ecologo products "environmentally friendly"?
Price	Available free on request
Distributor	Environmental Choice Program

Environmental Issues/An Overview

Format	Print
Annotation	CPA has produced a series of pamphlets on important environmental issues including sour gas, waste management, water quality and oil spills in Canada's frontiers. This pamphlet is an overview of the industry's concern for environmental matters, research and safety, industry and the community, industry and the government, and industry and the economy.
Price	Available free on request
Distributor	Canadian Petroleum Association

Fifty More Things You Can Do to Save The Earth (1989)

Format	Print	
Annotation	A summary of the environmental problems we face and practical things that young people can do to make a difference. (Authorized for EOE.)	
Price	$7.65	
Author	Earthworks Group	
Distributor	LRDC	0EV0729

Fifty Simple Things Kids Can Do to Save The Earth (1989)

Format	Print	
Annotation	A summary of the environmental problems we face and practical things that young people can do to make a difference. (Authorized for EOE.)	
Price	$8.75	
Author	J. Javna	
Distributor	LRDC	0EV07003

Focus on Research: A Guide to Developing Students' Research Skills (1990)

Format	Print	
Annotation	This document outlines a resource-based research model that helps students manage information efficiently and effectively, and in this process, to gain skills that are transferable to all school and work situations. This model provides a developmental approach to teaching students how to do research.	
Price	$3.60	
Author	Alberta Education, Curriculum Branch	
Distributor	LRDC	0XS01016

Gaia: An Atlas of Planet Management (1984)

Format	Print
Annotation	An examination of global human and environmental problems that threaten to disrupt and exhaust life support systems on Earth. Solutions to better planet management are proposed. This resource presents a left-wing bias which may be of concern to some people. (Authorized for EOE and Social Studies 20.)
Price	$17.95
Author	N. Myers (ed.)
Distributor	LRDC 0SS07076

Good Work Series (1988)

Format	Video (5 min each)
Annotation	A series of short documentaries that provide useful, up-to-date information on interesting occupations for young people.
Price	See ACCESS catalogue
Distributor	ACCESS 299401-299470

Green Future: How to Make a World of a Difference (1990)

Format	Print
Annotation	Explores major environmental issues and offers practical suggestions for daily positive action.
Price	$14.05
Author	L. Johnson
Distributor	LRDC 0EV07008

Health and Safety on the Job: Audio-Visual Catalogue (1992)

Format	Print (catalogue)
Annotation	Lists several AV resources available from Alberta Occupational Health and Safety Library Services
Price	Available free on request
Distributor	Alberta Occupational Health and Safety Library Services

Home and Family Guide: Practical Action for the Environment (1989)

Format	Print	
Annotation	Clear, practical information on how to tackle environmental issues in day-to-day life, recognizing that collectively we can have a tremendous influence on the environment. (Authorized for EOE.)	
Price	$6.20	
Author	Harmony Foundation of Canada; L. Ward-Whate	
Distributor	LRDC	0EV07026

Invitations to Science Inquiry (1990)

Format	Print	ISBN 1-878106-00-7
Annotation	Contains several demonstrations related to each of the science disciplines.	
Price	$40 U.S.	
Author	Tik Leim	
Distributor	Science Inquiry Enterprises	

Issues for Today, Canadian Environmental Concerns (1985)

Format	Print	
Annotation	Currently a support resource for Biology 10–20–30. (To be withdrawn June 30, 1993.)	
Price	$1.75	
Author	J. Marean	
Distributor	LRDC	0BI10011

Kananaskis Country Environmental Education Teaching Activity Guide: Earth Science (1987)

Format	Print
Annotation	This guidebook has three units: Earth History, Geologic Processes and Geologic Materials. Activities in each unit have been arranged by topics that elaborate on one or more key concepts in environmental education. These key concepts include: change, adaptation, ecosystems, interdependence, cycles, resources and technology. While building on the students' knowledge and skills, the activities also encourage an examination of personal values and attitudes (Authorized for EOE.)

Price	$29.25	
Author	R. Langsfeld, Calgary Board of Education	
Distributor	LRDC	0EV07028

Lab Safety : The Accident at Jefferson High

Format	Videocassette (18 min)	
Annotation*	Light humour is used to present important lessons on lab safety. When two bumbling officers are sent to investigate a science lab accident at a local school, they uncover the secrets to lab safety, such as how to use beakers, glass tubing, gas burners, and other lab apparatus and equipment; how to handle all kinds of chemicals; how to react properly to emergencies; and how to clean up.	
Price	See ACCESS catalog	
Distributor	ACCESS	VC340501

Levitating Trains And Kamikaze Genes: Technological Literacy for the 1990's (1991)

Format	Print	ISBN 0-060973692
Annotation	A guide to technological literacy with a list of topics on space technology, biotechnology, computer literacy, energy, superconductivity, high technology, health and transportation.	
Price	$8.95 U.S.	
Author	Richard P. Brennan	
Distributor	Harper Collins	

The Living Flow – Teaching Kit (1992)

Format	Print
Annotation	Includes teaching guide, 2 copies of the poster, and duplicating masters of information on the back of the poster.
Price	Available free on request
Distributor	Alberta Environment

Media Literacy Resource Guide (Intermediate and Senior Divisions) (1989)

Format	Print	
Annotation	Provides activity ideas using film, television, advertisements and other media for senior high classes. Also, presents summaries of the elements to analyze critically in each medium.	
Price	$9.25	
Author	Publications Ontario	
Distributor	LRDC	0SS07075

Natural Regions of Alberta – Poster Series (1990)

Format	Resource Manual and 5 posters	
Annotation	The main objective of the poster series and resource manual is to illustrate the beauty as well as the geological, geographical and environmental diversity in Alberta. It provides suggestions of activities to help teachers integrate posters into their daily lessons. (Authorized for Junior High Science.)	
Price	$29.95	
Author	Alberta Recreation, Parks and Wildlife	
Distributor	LRDC	0SC07042

Newton's First Law (1987)

Format	Video (27 min.)	
Annotation	Inservice training resource for teachers learning how to teach physics conceptually. Demonstrates the law of inertia.	
Price	See ACCESS catalogue	
Distributor	ACCESS	VC 305201

Newton's Third Law (1987)

Format	Video (27 min.)	
Annotation	Explains the law of action and reaction. Supplements class lectures and demonstrations, aids the teacher in preparing lectures and demonstrations, and acts as an inservice training resource for teachers learning how to teach physics conceptually.	
Price	See ACCESS catalogue	
Distributor	ACCESS	VC 305301

Occupational Health and Safety Publications List and Order Form

Format	Print
Annotation	Lists several publications available from Alberta Occupational Health and Safety
Price	Available free on request
Distributor	Alberta Occupational Health and Safety

Pesticide Education Program

Format: Kit (5 parts)

Annotation: This resource consists of 5 parts:

1. Forest Tent Caterpillar Study
2. Mosquito Kit
3. Vegetative Management Study
4. Pesticide Education Unit
5. Weed Kit

Each of the kits fit into the junior or senior science curricula. Kits 4 and 5 have the best fit with Science 10.

Price: Available free on request

Distributor: Alberta Environment

Problems in Chemistry (1990)

Format	Print ISBN 0-07-452665-0
Annotation	Each chapter contains a summary of key concepts and several questions related to the concepts. Part B gives complete answers to some questions, Part C gives only the answers.
Price	Not available
Author	Roland Smith
Distributor	McGraw-Hill Ryerson Ltd.

Professional Development Inservice Modules

Format: Print

Annotation:
System-Based Development Model for Workshops – A Planning Manual
Teaching for Thinking
STS Teaching Strategies
Controversial Issues in the Science Classroom
Focus on Research

Science 10 Activities: A Hands-On Sampler
Performance Assessment in Science 10
Technology and Media in the Science Classroom
Cooperative Learning
Teaching for Conceptual Change
Teaching with Gender Balance
Questioning Techniques for Science Teachers
Environmental Connections in the New Science Programs
Agriculture Connections in the New Science Programs

Price	$25	
Author	Alberta Education	
Distributor	LRDC	0SC10128

Project Wild: Secondary Activity Guide (1985)

Format	Print
Annotation	A collection of interdisciplinary and supplementary environmental education materials emphasizing wildlife conservation. Activities are indexed by topic, grade, subject and skill. (Authorized for EOE.)
Price	Available free on request
Distributor	Alberta Forestry, Lands and Wildlife, Fish and Wildlife Division, Conservation Education

Recognizing Herbicide Action and Injury

Format	Print
Annotation	Discover how to recognize the symptoms of herbicide-related causes of crop injury. Learn the preventative steps. Understand the way your herbicides work – how they move into plants and where they go once inside the plants. Get to know where they move in the soils and how long they stay there. See what to look for when examining crops for damage and when checking weeds for signs of killing action.
Price	$8
Distributor	Alberta Agriculture

Safety and Organization in School Science Facilities (1990)

Format	Print
Annotation	Guidelines for lab safety, checklists, fire prevention, radiation protection, safety with biological chemicals
Price	Available free on request
Author	Science Education Consultants' Council, Alberta Education
Distributor	Regional Offices of Education - Science Consultants

---

Science Process and Discovery, Second Edition (1985)

Format: Print ISBN 0-201-18628-4

Annotation:

- Examines significant events in the history of science and topics of current research through the use of short case studies.
- Written for the general level science student but allows deeper analysis of the scientific method for the more advanced student.
- Short narrative articles are followed by two different questions sets.
- Analysis provokes thinking about the cycles of proof and scientific principles.
- Accompanying Teacher's Guide contains objective questions for each narrative.

Price	Student book $14.25 U.S.; Teacher's Guide, price not available
Author	Dennis Field
Distributor	Addison-Wesley Publishers Limited

Science 10 Item Bank
(Science 20, Biology 20, Chemistry 20 and Physics 20 item banks are under development)

Format: Currently only available in the Macintosh format (or hard copy from LRDC)

Annotation: This is a collection of test items created "by teachers for teachers." The items have been submitted by Science 10 field validation teachers, Alberta Education Program Consultants and Student Evaluation Branch Test Development Specialists. The items have been entered into LXR TESTS and edited by Alberta Distance Learning Centre personnel. The item bank is constantly under revision so teachers should arrange for periodic updates. To acquire the itembank, simply send a disk(s) to ADLC requesting the most recent version and the disk will be returned to you.
Note: You must have LXR TEST software to access the item bank questions on disk.

Price	Available free on request
Distributor	Alberta Distance Learning Centre

SEEDS: Energy Literacy Series (1983)

Format	Print
Annotation	Useful as a reference for energy activities for students. Student and teacher materials are available. The series consists of several components • Renewable Sources of Energy • Energy Technologies • Energy in the Future • Energy Systems • Sources of Electrical Energy • Nonrenewable Sources of Energy Copies of these materials have been distributed to every high school in Alberta.
Price	Additional copies of the Teacher's Guide can be purchased for $10.00. Student Books are no longer available but copyright permission is released with purchase of the Teacher's Guide.
Distributor	SEEDS

Senior High English Teacher Resource Manual (1991)

Format	Print	
Annotation	This TRM offers additional teaching strategies (e.g., developing writing, listening and speaking skills) related to language arts learning but which may also be useful in senior high science classes.	
Price	$14.10	
Author	Alberta Education, Curriculum Branch	
Distributor	LRDC	0XS10025

Sexually Transmitted Disease Teaching Outline and Resource Guide (1988)

Format	Print	
Annotation	This resource has been developed to assist teachers and educators involved in the presentation of S.T.D. information to school students or similar groups. Included in the guide is information on S.T.D.s, a sample presentation outline, student learning activities and a list of resources.	
Price	$1	
Author	Alberta Health	
Distributor	LRDC	0HL09012

Somebody Should Do Something About This (1992)

Format	Print
Annotation	This resource is designed as a teacher's resource book on energy and the environment. It will provide teachers with background information on non-renewable energy sources, renewable energy sources, energy conservation and energy efficiency, and the environmental effects related to energy use and production. It is divided into sections for easy use: activities, factsheets, additional resources, and an index with an alphabetical listing of energy and environmental terms.
Price	Available free on request
Distributor	Alberta Energy

Strategem

Format	Game/Kit
Annotation	Kit includes 4 game boxes, photocopy masters, teachers guide, 7 min. video, IBM diskette. Support for Social Studies 20. Alberta Energy may be able to provide a teacher workshop if enough interest generated.
Price	$222.30 or borrow free from Alberta Energy (Macintosh diskette also available)
Distributor	LRDC 0SS20001

STS Science Education: Unifying the Goals of Science (1990)

Format	Print
Annotation	Provides a comprehensive description that will help teachers integrate the STS concept into their teaching schemes
Price	$3.05
Author	F. Jenkins
Distributor	LRDC 0XS10017

Teaching Skillful Thinking: A Staff Development Program for Education (1986)

Format	Kit
Annotation	Includes 4 videos and 1 user guide
Price	$551.10
Distributor	LRDC 0VT00001

Teaching Thinking: Enhancing Learning (1990)

Format	Print
Annotation	Principles and guidelines for cultivating thinking, ECS to Grade 12, have been developed in this resource. It offers a definition of thinking, and describes nine basic principles on which the suggested practices are based and discusses possible procedures for implementation in schools and classrooms.
Price	$4.25
Author	Alberta Education, Curriculum Branch
Distributor	LRDC 0XS00125

Together We Learn (Cooperative and Small-Group Learning) (1990)

Format: Print/Video

Annotation: Together We Learn has been designed as a practical "how-to" handbook to help teachers implement small group learning strategies in their classrooms. The book offers the following to teachers:

- A nuts-and-bolts approach to cooperative learning that provides student classroom suggestions and aids.
- Thorough coverage of cooperative learning approaches to assist teachers of varying levels of experience with group work.
- Suggestions that are relevant to all grades, disciplines and students.
- A jargon-free easy-to-read treatment of cooperative learning techniques.

Video available from ACCESS.

Price: $30.75

Author: R. Wideman, et al.

Distributor: LRDC 0SS07073

Tour TransAlta

Format	Print (brochure)
Annotation	Describes free guided tours of TransAlta's generating plants and mining operations.
Price	Available free on request
Distributor	TransAlta Utilities

Toward a Common Future: A Report on Sustainable Development and Its Implications for Canada (1989)

Format	Print
Annotation	Provides information related to sustainable development. Discusses major issues such as atmosphere, land, water, chemicals, wastes and garbage, and implications for government, business, industry, public interest groups, education and individuals.
Price	Not available
Author	Michael Keating
Distributor	Environment Canada

Two Minutes a Day for a Greener Planet (1990)

Format	Print	
Annotation	Quick and simple things you can do to save the Earth. (Authorized for EOE.)	
Price	$4.20	
Author	M. Lamb	
Distributor	LRDC	0EV07005

Water Quality Questions: The Nature and Importance of Water Quality Variables in Alberta (1988)

Format	Print	
Annotation	Uses the topics of Alberta water to bridge scientific, technological and social aspects in a relevant and realistic way for Alberta students. The package includes a student booklet, a teacher's guide, "River Monitoring" masters and overhead transparencies. The program also includes a special "indoor field study." (Authorized for Junior High Science.)	
Price	Teacher Package $18.50 (available free with workshop) Student Package $1.95	
Author	Alberta Environment	
Distributor	LRDC	Teacher Package 0SC07055 Student Package 0SC07056

The Weather Companion - An Album of Meteorological History, Science, Legend and Folklore (1988)

Format	Print	ISBN 0-471-62079-3
Annotation	Contains chapters "Weather Past," "Weather Tools," "Weather Phenomenon," "Storm Warnings," "Weather and Wildlife," "Botanical Weather," "The Weather, You, and Me."	
Price	$12.95 U.S.	
Author	Gary Lockhart	
Distributor	John Wiley and Sons, Inc.	

Weeds of Alberta

Format	Print
Annotation	Learn to identify 93 common weeds. Get to know where they tend to grow, what features you can use to make a positive identification and why each weed is an agricultural concern. This lavishly illustrated book features color photos and illustrations of whole mature plants, seedlings, seeds and flowers. It is the most complete work of its kind on the weeds of the Canadian Prairies.
Price	$15
Distributor	Alberta Agriculture

What Can We Do For Our Environment: Hundreds of Things To Do Now

Format	Print
Annotation	Hundreds of ideas for things each of us can do to protect and improve our environment. (Authorized for EOE.)
Price	Available free on request (limited availability)
Distributor	Environment Canada

World Issues in the Global Community (1989)

Format	Print	
Annotation	Basic resource Social Studies 23; Teachers Manual is support resource.	
Price	$33.15 (basic resource); $33.70 (teacher manual)	
Author	R. Harshman	
Distributor	LRDC	0SS11036 (basic resource)
	LRDC	0SS23001 (teacher manual)

RESOURCE/MEDIA CENTRES

There are 12 resource/media centres in Alberta that carry films and videos that support the Science 14/24 program. Each centre publishes its own catalogue, listing the resources in its collection. These centres operate as libraries, lending out audiovisual materials for specified time periods. For more information teachers should contact their local resource/media centre. See the attached list.

REGIONAL RESOURCE CENTRES

Zone 1 Zone One Regional Film Centre P.O. Box 6536 10020 – 101 Street Peace River, Alberta T8S 1S3 Telephone (403) 624-3187	**Zone 2/3** Central Alberta Media Services (CAMS) 2017 Brentwood Boulevard Sherwood Park, Alberta T8A 0X2 Telephone (403) 464-5540 467-8896
Zone 4 Alberta Central Regional Educational Services (ACRES) County of Lacombe Box 3220 5140 – 49 Street Lacombe, Alberta T0C 1S0 Telephone (403) 782-5730	**Zone 5** South Central Alberta Film Federation (SCAFF) Westmount School Box 90 Wheatland Trail Strathmore, Alberta T0J 3H0 Telephone (403) 934-5028
Zone 6 Southern Alberta Regional Film Centre (SAFRC) McNally School P.O. Box 845 Lethbridge, Alberta T1J 3Z8 Telephone (403) 320-7807	

URBAN MEDIA CENTRES

County of Strathcona Learning Resource Service 2001 Sherwood Drive Sherwood Park, Alberta T8A 3W7 Telephone (403) 464-8235	**Red Deer Public School Board** 4747 - 53 Street Red Deer, Alberta T4N 2E6 Telephone (403) 343-1405
Calgary Separate School Board Instructional Materials 6220 Lakeview Drive S.W. Calgary, Alberta T3E 6T1 Telephone (403) 246-6663	**Calgary Board of Education** Education Media 3610 - 9th Street S.E. Calgary, Alberta T2G 3C5 Telephone (403) 294-8540
Edmonton Public School Board Learning Resources Centre Centre for Education One Kingsway Edmonton, Alberta T5H 3G9 Telephone (403) 429-8320	**Medicine Hat School District** Instructional Materials Centre 601 First Avenue S.W. Medicine Hat, Alberta T1A 4Y7 Telephone (403) 526-1323
Edmonton Catholic Schools Curricular Resources St. Anthony's Teacher Centre 10425 - 84 Avenue Edmonton, Alberta T6E 2H3 Telephone (403) 439-7356	

Regional Offices

Grande Prairie Regional Office Contact: Blain Askew 12th Floor, 214 Place 9909-102 Street Grande Prairie, Alberta T8V 2V4 Telephone (403) 538-5130 Fax (403) 538-5135	**Red Deer Regional Office** Contact: Fred Nordby 3rd Floor, West Provincial Building 4920-51 Street Red Deer, Alberta T4N 6K8 Telephone (403) 340-5262 Fax (403) 340-5305
Edmonton Regional Office Contact: Wilf Green/Ken Kluchky Mailing Address: 11160 Jasper Avenue Edmonton, Alberta T5K 0L2 Telephone (403) 427-2952 Fax (403) 422-9682	Street Address: 7th Floor, Westcor Building 12323 Stony Plain Road Edmonton, Alberta
Calgary Regional Office Contact: Greg Thomas 1200 Rocky Mountain Plaza 615 Macleod Trail, S.E. Calgary, Alberta T2G 4T8 Telephone (403) 297-6353 Fax (403) 297-3842	**Lethbridge Regional Office** Contact: Terry Rusnack Provincial Building 200-5th Avenue, South Lethbridge, Alberta T1J 4C7 Telephone (403) 381-5243 Fax (403) 381-5734

Distributor Information

ACCESS NETWORK Media Resource Centre 295 Midpark Way SE Calgary, AB T2X 2A8 1–800–352–8293	Addison-Wesley Publishers Limited 26 Prince Andrew Place P.O. Box 580 Don Mills, ON M3C 2T8 Telephone (416) 447–5101 Fax (416) 443–0948
Alberta Distance Learning Centre Box 4000 Barrhead, AB T0G 2P0 Telephone (403) 674–5333 Fax (403) 674–6561	Alberta Energy Energy Efficiency Branch Education Services 7th Floor, 9945 - 108 Street Edmonton, AB T5K 2G6 Telephone (403) 427-5200 Fax (403) 422–0494
Alberta Environment Education Branch 12th Floor, 9820 - 106 Street Edmonton, Alberta T5K 2J6 Telephone (403) 427-6310 Fax (403) 427–2512	A.J. Tech 12042 – 77 Street Edmonton, AB T5B 2G7 Telephone (403) 479–3472 Fax (403) 477–3313
Alberta Agriculture Educational Services 7000- 113 Street Edmonton, AB T6H 5T6 Telephone (403) 427-2402 Fax (403) 438-3362	Alberta Forestry, Lands and Wildlife Fish and Wildlife Division 10th Floor, 9920 - 108 Street Edmonton, AB T5K 2C9 Telephone (403) 427-3590 Fax (403) 427-0292
Alberta Public Affairs Bureau Publication Services 11510 Kingsway Avenue Edmonton, AB T5G 2Y1 Telephone (403) 427-4952 Fax (403) 452-0668	Alberta Special Waste Management Corporation Communications Suite 610, 10909 - Jasper Avenue Edmonton, AB T5J 3L9 Telephone (403) 422-5029 Fax (403) 428–9627
Canadian Petroleum Association Safety, Health and Environment #3800, 150 - 6 Avenue S.W. Calgary, AB T2P 3Y7 Telephone (403) 269-6721 Fax (403) 261-4622	Computerland The Allarco Building 11452 Jasper Avenue Edmonton, AB T5K 0M1 Telephone (403) 482–5625 Fax (403) 482–7206

Coronet 1870 Birchmount Road Scarborough, ON M1P 2J7 Telephone (416) 293-3621 Fax (416) 299-2539	CRC Press Inc. 2000 Corporate Blvd., N.W. Boca Raton, FL 33431 U.S.A. Fax (407) 997-0949)
D.C. Heath Canada Ltd. Suite 1600 100 Adelaide Street W. Toronto, ON M5H 1S9 Telephone: (416) 362-6483 Fax: (416) 362-7942	Environment Canada Room 210 4990 - 98 Avenue Edmonton, AB T6B 2X3 Telephone (403) 468-8075
Environment Council of Alberta Suite 400 9925 - 109 Street Edmonton, AB T5K 2J8 Telephone (403) 427-5792	Environmental Choice Program 107 Sparks Street, 2nd Floor Ottawa, ON Fax (613) 952-9465
Environmental Resource Centre 10511 Saskatchewan Drive Edmonton, AB T6E 4S1 Telephone (403) 433-8711	Facts on File P.O. Box 920, Station "U" Toronto, ON M8Z 5P9 Telephone (416) 251-1822/1119 Fax (416) 251-3679
Friends of Environmental Education Society of Alberta #320, 9939 Jasper Avenue Edmonton, AB T5J 2X5 Telephone (403) 439-0243 Fax (403) 432-1203	Harper and Collins Books of Canada Ltd. 1995 Markham Road Scarborough, ON M1B 5M8 Telephone (416) 975-9334 Fax (416) 975-9884 Toll Free 1-800-387-0117
John Wiley and Sons Canada Ltd. 5353 Dundas Street West, 4th FLoor Etobicoke, ON M9B 6H8 Telephone: (416) 674-0240 Fax: (416) 674-1313	Learning Resources Distributing Centre (LRDC) 12360 - 142 Street Edmonton, AB T5L 4X9 Phone (403) 427-2767
Logic eXtension Resources 9651-C Business Centre Drive Rancho Cucamonga, CA 91730-4537 U.S.A. Fax (714) 987-8706 AppleLink D0626	Maxwell MacMillan Canada 539 Collier MacMillan Drive Cambridge, ON N1R 5W9 Telephone (416) 265-8672 Fax: (416) 449-0068

McGraw-Hill Ryerson Ltd. 624 Deer Path Court Calgary, AB T2J 6C4 Telephone (403) 271–8042	McIntyre Media Limited 30 Kelfield Street Rexdale, ON M9W 5A2 Telephone (416) 245–7800 Fax (416) 245–8660
Merlan Scientific 247 Armstrong Avenue Georgetown, ON L7G 4X6 Telephone (800) 387–2474 Fax (416) 877–0929	Mosby Year Book C.V. Mosby Co. Ltd. 5240 Finch Avenue East, Unit 1 Scarborough, ON M1S 4P2 Telephone (416) 298–1588 Fax (416) 298–8071
Nelson Canada 1120 Birchmount Road Scarborough, ON M1K 5G4 Telephone (416) 752–9100 Fax (416) 752–9646	Occupational Health and Safety Local offices in Edmonton, Calgary, Grande Prairie, Red Deer and Lethbridge
Occupational Health and Safety Library Services 6th Floor, 10709 Jasper Avenue Edmonton, AB T5J 3N3 Telephone (403) 427–3530 Fax (403) 427–5698	Optical Data Corporation 30 Technology Drive Warrent, NJ 07059 U.S.A. Telephone (908) 668–0022
Optilearn P.O. Box 997 401 Indiana Avenue Stevens Point, WI 54481-0997 U.S.A. Telephone (715) 344-6060 Fax (715) 344-1066	Pembina Institute for Appropriate Development Box 7558 Drayton Valley, AB T0E 0M0 Telephone (403) 542–6272 Fax (403) 542–6464
Perceptix Inc. Suite 1014 111 Richmond Street West Toronto, ON M5H 2J5 Telephone (416) 365–1704 Fax (416) 365–7463 Toll Free 1–800–267–7788	Quantum Technology Inc. P.O. Box 8252 2920 E Moore Street Searcy, AR Telephone (303) 674–9651
Science Inquiry Enterprises 505–12 W. Madison Avenue, Apt. 12 El Cajon, CA 92020 Telephone (714) 590–4618	SEEDS Foundation 440, 10169 - 104 Street Edmonton, AB T5J 1A5 Telephone (403) 424-0971

Technovision Inc. 5155 Spectrum Way, Unit 31 Mississauga, ON L4W 5A1 Telephone (416) 625-3472 Fax (416) 625-4784	TransAlta Utilities Public Affairs 110 - 12 Avenue S.W. Calgary, AB T2P 2M1 Telephone (403) 267-7459
Videodiscovery 1700 Westlake Avenue N Suite 600 Seattle, WA 98109-3012 Telephone (206) 285-5400 Fax (206) 285-9245	