SENIOR 3 CURRENT TOPICS IN THE SCIENCES: SUGGESTIONS FOR INSTRUCTION AND ASSESSMENT

Linking General and Specific Learning Outcomes to Suggestions for Instruction and Assessment

In Senior 3 Current Topics in the Sciences, the following four General Learning Outcome (GLO) foundation areas often operate simultaneously, rather than consecutively or in isolation:

- GLO A: Nature of Science and Technology
- GLO B: Science, Technology, Society, and the Environment (STSE)
- GLO C: Scientific and Technological Skills and Attitudes
- GLO D: Essential Concepts

The learning outcomes are listed on the following page.

The unique instructional design of *Senior 3 Current Topics in the Sciences: A Foundation for Implementation* (with its emphasis on local decision making about content) naturally demands a different set of document characteristics than what Manitoba science teachers have grown accustomed to. For instance, this curriculum document *cannot* become operational by beginning with GLO A, and then proceeding to GLO B, and so on. What the document does provide—together with its key support document *Senior Years Science Teachers' Handbook* (Manitoba Education and Training)—are suggestions for instruction and assessment that relate in particular ways to one of the four foundation areas.

Therefore, if teachers are involved in a component of a particular unit that has an emphasis on the nature of science, they will want to consult one or more of the instructional and assessment strategies suggested within the section of this document entitled GLO A: Nature of Science and Technology. If the tasks at hand take more skills or mastery learning-based approaches, teachers will identify productive strategies within the section entitled GLO C: Scientific and Technological Skills and Attitudes.

It is important to recognize that this section of the document also provides a *constructivist approach* to the teaching and learning cycle (Activating, Acquiring, and Applying), and assessment priorities can be summarized as follows:

- Identify the targeted learning outcomes as having come *naturally* from the context of the science content in a unit of study.
- Formulate a set of priorities for teaching and learning.
- Carefully select and implement teaching and learning strategies that will be successful with students and their learning climate.
- Assess, along the way, through observation of processes and student products.
- Record, for reporting purposes, appropriate information for students, their parents, and other educators and stakeholders.

General and Specific Learning Outcomes for Senior 3 Current Topics in the Sciences

GLO A: NATURE OF SCIENCE AND TECHNOLOGY
Differentiate between science and technology, recognizing their strengths and limitations in furthering our understanding of the world, and appreciate the relationship between culture and technology.

SLO A1: Distinguish critically between science and technology in terms of their respective contexts, goals, methods, products, and values.

SLO A2: Recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena.

SLO A3: Identify and appreciate the manner in which history and culture shape a society's philosophy of science and its creation or use of technology.

SLO A4: Recognize that science and technology interact and evolve, often advancing one another.

SLO A5: Describe and explain disciplinary and interdisciplinary processes used to enable us to investigate and understand natural phenomena and develop technological solutions.

GLO B: SCIENCE, TECHNOLOGY, SOCIETY, AND THE ENVIRONMENT
Explore problems and issues that demonstrate interdependence among science, technology, society, and the environment.

SLO B1: Describe scientific and technological developments, past and present, and appreciate their impact on individuals, societies, and the environment, both locally and globally.

SLO B2: Recognize that scientific and technological endeavours have been, and continue to be, influenced by human needs and by societal and historical contexts.

SLO B3: Identify the factors that affect health and explain the relationships of personal habits, lifestyle choices, and human health, both individual and social.

SLO B4: Demonstrate a knowledge of, and personal consideration for, a range of possible science- and technology-related interests, hobbies, and careers.

SLO B5: Identify and demonstrate actions that promote a sustainable environment, society, and economy, both locally and globally.

GLO C: SCIENTIFIC AND TECHNOLOGICAL SKILLS AND ATTITUDES
Demonstrate appropriate inquiry, problem-solving, and decision-making skills and attitudes for exploring scientific and/or technological issues and problems.

SLO C1: Demonstrate appropriate scientific inquiry skills, attitudes, and practices when seeking answers to questions.

SLO C2: Demonstrate appropriate technological problem-solving skills and attitudes when seeking solutions to challenges and problems related to human needs.

SLO C3: Demonstrate appropriate critical thinking and decision-making skills and attitudes when choosing a course of action based on scientific and technological information.

SLO C4: Employ effective communication skills and use a variety of resources to gather and share scientific and technological ideas and data.

SLO C5: Work cooperatively with others and value their ideas and contributions.

GLO D: ESSENTIAL CONCEPTS
Explore, understand, and use scientific knowledge in a variety of contexts.

SLO D1: Use the concepts of similarity and diversity for organizing our experiences with the world.

SLO D2: Recognize that the universe comprises systems and that complex interactions occur within and among these systems at many scales and intervals of time.

SLO D3: Understand the processes and conditions in which change, constancy, and equilibrium occur.

SLO D4: Understand how energy is the driving force in the interaction of materials, processes of life, and the functioning of systems.

General Learning Outcome A

Nature of Science and Technology

GLO A

Differentiate between science and technology, recognizing their strengths and limitations in furthering our understanding of the world, and appreciate the relationship between culture and technology.

Overview

Students learn that science and technology are creative human activities with long histories in all cultures.

Science is a way of learning about the universe. This learning stems from curiosity, creativity, imagination, intuition, exploration, observation, replication of experiments, interpretation of evidence, and debate over that evidence and its interpretations. Scientific activity involves predicting, interpreting, and explaining natural and human-made phenomena. Many historians, sociologists, and philosophers of science presently argue that there is no definable, set procedure for conducting a scientific investigation. Rather, they see science as driven by a combination of theoretical concerns, knowledge, experiments, and processes anchored in the physical world.

Technology results mainly from proposing solutions to problems arising from human attempts to adapt to the external environment. "Technology" refers to much more than the knowledge and skills related to devices such as computers, peripherals, and their applications.

Technology is based on the knowledge of concepts and skills from many disciplines (including science), and is the application of this knowledge to meet an identified need or to solve a problem using materials, energy, and tools (including computers). Technology also has an influence on processes and systems, on society, and on the ways people think, perceive, and define their world.

Specific Learning Outcomes

SLO A1: Distinguish critically between science and technology in terms of their respective contexts, goals, methods, products, and values.

SLO A2: Recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena.

SLO A3: Identify and appreciate the manner in which history and culture shape a society's philosophy of science and its creation or use of technology.

SLO A4: Recognize that science and technology interact and evolve, often advancing one another.

SLO A5: Describe and explain disciplinary and interdisciplinary processes used to enable us to investigate and understand natural phenomena and develop technological solutions.

General Learning Outcome A

Students will...

Differentiate between science and technology, recognizing their strengths and limitations in furthering our understanding of the world, and appreciate the relationship between culture and technology.

Specific Learning Outcome

SLO A1: Distinguish critically between science and technology in terms of their respective contexts, goals, methods, products, and values.

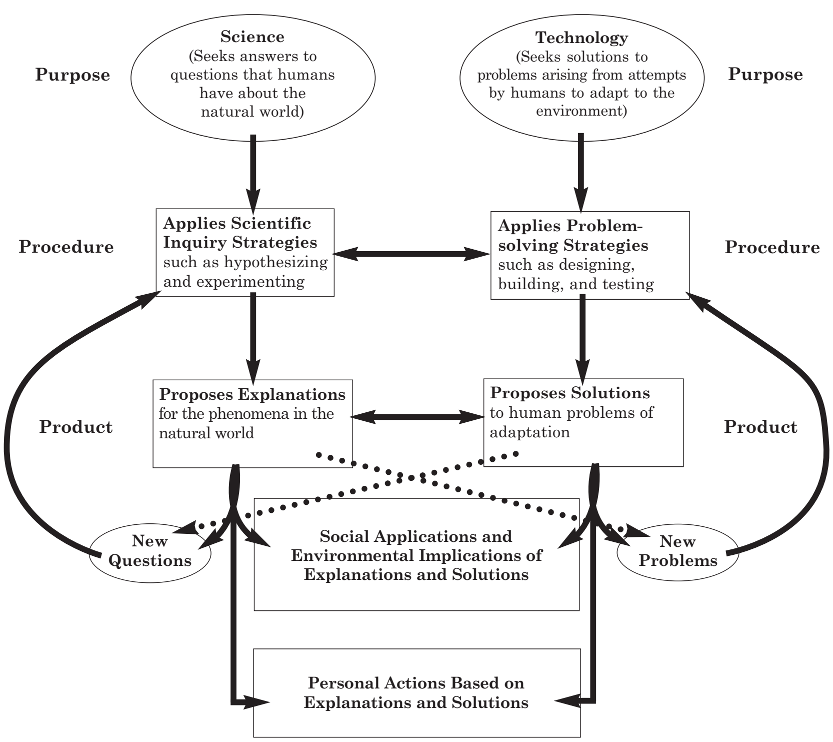
Suggestions for Instruction

Teacher Background

Science and technology are creative human activities with long histories in all cultures of the world. Science is a way of learning about the universe, satisfying curiosity, and producing knowledge about events and phenomena in the natural world. Technology provides effective and efficient ways for humans to accomplish tasks or meet needs. (See illustration below.)

Scientific learning stems from curiosity, creativity, imagination, intuition, exploration, observation, replication of experiments, interpretation of evidence, and debate over the evidence and its interpretations. Scientific activity involves predicting, interpreting, and explaining natural and human-made phenomena. Many historians, sociologists, and philosophers of science argue that there is no set procedure for conducting a scientific investigation.

Science and Technology: Their Nature and Interrelationships



Science and Technology: Their Nature and Interrelationships: Adapted with permission from Rodger W. Bybee, et al., *Science and Technology Education for the Elementary Years: Frameworks for Curriculum and Instruction* (Rowley, MA: The NETWORK, Inc., 1989).

Suggestions for Instruction

> Producing science knowledge is an intrinsically collective endeavour. There is no such thing as stand-alone science. Scientists submit models and solutions to the assessment of their peers who judge their logical and experimental soundness by reference to the body of existing knowledge. (Larochelle and Désautels 235)

Scientific theories are being tested, modified, and refined continually as new knowledge and theories supersede existing knowledge bases. Scientific debate, both on new observations and on hypotheses that challenge accepted knowledge, involves many participants with diverse backgrounds.

This highly complex interplay, which has occurred throughout history, is animated by theoretical discussions, experimentation, social, cultural, economic, and political influences, personal biases, and the need for peer recognition and acceptance. Students will realize that while some of our understandings about how the world works are due to revolutionary scientific developments, many of our understandings result from the steady and gradual accumulation of knowledge.

History demonstrates, however, that great advances in scientific thought have completely uprooted certain disciplines, transplanting practitioners and theoreticians alike into an entirely new set of guiding assumptions. Such *scientific revolutions*, as discussed by Thomas S. Kuhn in his influential *The Structure of Scientific Revolutions,* constitute exemplars that can energize the science teaching enterprise, and provide particularly motivating and novel contexts for students.

Technology is concerned mainly with proposing solutions to problems arising from attempts by humans to adapt to the environment. Technology may be regarded as "a tool or machine; a process, system, environment, epistemology, and ethic; the systematic application of knowledge, materials, tools, and skills to extend human capabilities" (Manitoba Education and Training, *Technology As a Foundation Skill Area* 1).

Technology includes much more than the knowledge and skills related to devices such as computers and their applications. It is both a form of knowledge that uses concepts and skills from other disciplines (including science) and the application of this knowledge to meet an identified need or solve a problem using materials, energy, and tools (including computers). Technology also has an impact on processes and systems, on society, and on the ways people think, perceive, and define their world.

Activating

Prior Knowledge Activities

- Students examine the hot coffee example in the Processes for Science Education model. Students create other examples to fit the model.

Processes for Science Education

	Scientific Inquiry	Technological Problem Solving (Design Process)	Decision Making
Purpose:	Satisfying curiosity about events and phenomena in the natural world.	Coping with everyday life, practices, and human needs.	Identifying different views or perspectives based on varying information.
Procedure:	What do we know? What do we want to know?	How can we do it? Will it work?	What are the alternatives or consequences? Which choice is best at this time?
Product:	Knowledge about events and phenomena in the natural world.	An effective and efficient way to accomplish a task or meet a need.	A defensible decision in a particular circumstance.

	Scientific Question	Technological Problem	STSE Issue
Example:	Why does my coffee cool so quickly? *An Answer:* Heat energy is transferred by conduction, convection, and radiation to the surrounding environment.	How can I keep my coffee hot? *A Solution:* A plastic foam cup will keep liquids warm for a long time. So will an insulated cup.	Should we use plastic foam cups or ceramic mugs for our meeting? *A Decision:* Since we must use disposable cups for the meeting, we will choose a biodegradable type.

Processes for Science Education: Adapted with permission of the Minister of Education, Province of Alberta, Canada, 2005.

- Students use a Compare and Contrast Frame (*SYSTH** 10.24) to make a critical distinction between science and technology.

* *SYSTH* refers to *Senior Years Science Teachers' Handbook* (Manitoba Education and Training).

Suggestions for Instruction

Acquiring

Development of Concepts

- Students use a Compare and Contrast Frame (*SYSTH* 10.20, 10.24) to distinguish between scientific questions and technological problems.

  Examples:

Scientific Question	versus	Technological Problem
• "What is the mechanism responsible for the movement of continents?" • "How does the human body react in a weightless environment?" • "What is a cell?"		• "How could one measure the rate at which two continents are separating?" • "How can we counter the negative effects of weightlessness on a human body?" • "How can a person see organelles inside a cell?"

- Students explain how scientific knowledge evolves as new evidence comes to light and as theories are tested and subsequently restricted, revised, or replaced.

  Examples:

  — Students explain how fossil data contributed to the theory of the evolution of species.

  — Students explain how seismic, fossil, and geological data contributed to the theory of plate tectonics.

Applying

Case Study

- Students explain how scientific knowledge has led to the development of a technological product.

  Examples:

  — kidney dialysis machine

  — laparoscope

  — magnetic resonance imaging (MRI) scanner

  — artificial heart

- Students explain how a scientific or technological milestone revolutionized thinking within a scientific community or research program.

  Examples:

  — How did field theory assist scientists in understanding the motions of celestial bodies or the movement of particles in a magnetic field?

  — How did Pasteur's experiments contribute to an understanding of micro-organisms and disease?

Suggestions for Assessment

- Students use a Concept Organizer Frame such as the Concept Frame or the Concept Overview (*SYSTH* 11.35-11.37) to summarize learning related to the concepts of science and technology. The type of Concept Frame used can be determined by the teacher or by individual students. Some students may prefer to use one frame over another. The frames can be handed in for teacher feedback. As this strategy is intended as a **formative assessment** to check student understanding, a formal, recorded grade for this task is not required.
- A summary of the categories used for each frame is provided below. For more details and blackline masters, refer to *SYSTH* (11.23-11.24, 11.36-11.37).

Concept Frame	Concept Overview
• Concept • Characteristics • Examples • Comparison (What is it like?) • Contrast (What is it unlike?) • Definition • Illustration	• Key word or concept • Figurative representation • Explanation or definition in own words • Facts • Self-generated questions about the concept • Analogy

- *SYSTH* and Appendix 7 offer a variety of assessment strategies that can be linked to specific instructional approaches and the particular needs of students.

General Learning Outcome A

Students will…

Differentiate between science and technology, recognizing their strengths and limitations in furthering our understanding of the world, and appreciate the relationship between culture and technology.

Specific Learning Outcome

SLO A2: Recognize both the power and limitations of science as a way of answering questions about the world and explaining natural phenomena.

Suggestions for Instruction

Activating

Prior Knowledge Activity

- Brainstorm to generate class discussion on the extent to which science has answered questions about the world and explained natural phenomena, and on further questions that have then arisen.

Acquiring

- Students read and report on a biography or an autobiography of a scientist, looking at the progression and development of scientific understanding.

  Example:

  — *The Double Helix* by James Watson
- Students generate a list of scientific questions and technological problems related to the scientist's work in each of the following categories.

  The scientist

  — has an answer or solution

  — does not have an answer or solution

  — has a limited answer or solution

Applying

- Students identify instances in which science and technology have been limited in their ability to find answers to questions or to the solution of problems.

  Examples:

  — What is the cause(s) of cancer? How is cancer treated? How long will a person who has cancer live?

  — How did life on Earth first develop?

  — What is the inside of the Earth made of?

  — How can we establish a permanent colony in space?

  — How do we explain geological changes on the Earth's surface?

  — What are the causes and treatments of acquired immune deficiency syndrome (AIDS) and severe acute respiratory syndrome (SARS)?

Suggestions for Assessment

- Students critically analyze a piece of scientific writing, such as an article in a scientific journal.
- For a detailed synopsis of how treatment of science writing can be included as an imperative in assessing student's literacy standing, refer to *SYSTH* (Chapter 14).

Teacher Notes

General Learning Outcome A

Students will...

Differentiate between science and technology, recognizing their strengths and limitations in furthering our understanding of the world, and appreciate the relationship between culture and technology.

Specific Learning Outcome

SLO A3: Identify and appreciate the manner in which history and culture shape a society's philosophy of science and its creation or use of technology.

Suggestions for Instruction

Activating

Prior Knowledge Activity

- Hold a class discussion on societal views of science: *Do different societies have different philosophical views of science? How might a society's philosophy of science and technology be shaped by history and culture?*

  Examples:

  — North American indigenous cultures

  — Asian cultures

  — East Indian cultures

Acquiring

Research

- Students research the contributions to scientific and technological development made by women and men from many societies and cultural backgrounds.
- Students research the development of a particular body of knowledge in science within a society/culture and make a timeline. Different groups may then share and compare their results.

  Examples:

  — knowledge and understanding of the universe

  — knowledge and understanding of disease
- Students research and compare the development of similar research programs in science and technology in different countries. They use a multi-perspective approach, considering scientific, technological, economic, cultural, political, and local environmental factors.

  Examples:

  — space travel

  — medical technologies

  — nuclear power

Applying

Debate

- Students use the debating process to analyze how research programs in science and technology are publicly supported, funded, and influenced by the pressures of priority, merit, and foreseeable influences on the lives of communities.

  Examples:

  — Debate the merits and demerits of funding research in the development of drugs to combat symptoms of AIDS rather than the medical aspects of alcoholism and fetal alcohol syndrome (FAS).

  — Debate the role of pharmaceutical companies in developing new treatments for disease.

  — Debate the relevance of space exploration to life on Earth.

  — Debate the role of homeopathic versus mainstream medical treatments.

  — Debate the importance of the preservation of endangered species of plants and animals to life on Earth.

Suggestions for Assessment

- Students research and analyze the development of science or technology in response to a historical event. Acting as reporters from that time period, they write a news article to illustrate a particular social and historical perspective of a selected topic or scientific advancement.

  Examples:

  — 1944: How did the events of World War II affect the development and use of the atomic bomb?

  — 1632: How did the Copernican view of the universe influence society?
- Students design a new technology or invention and develop a local, national, or global implementation plan for a new idea, taking into account scientific, technological, economic, cultural, political, and environmental factors.

General Learning Outcome A

Students will...

Differentiate between science and technology, recognizing their strengths and limitations in furthering our understanding of the world, and appreciate the relationship between culture and technology.

Specific Learning Outcome

SLO A4: Recognize that science and technology interact and evolve, often advancing one another.

Suggestions for Instruction

Activating

Prior Knowledge Activity

- In a class discussion, produce a web showing the interconnections between science and technology, using specific examples generated by the students.

Acquiring

Development of Concepts

- Students identify, analyze, and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology.

  Examples:

  — Investigate and describe how seismology has assisted geoscientists in furthering our understanding of the Earth's interior through applications such as seismic tomography.

  — How did the development of the telescope alter society's understanding of the universe and humanity's place within it?

  — How did the refinement of X-ray crystallography techniques lead to the determination of the structure of deoxyribonucleic acid (DNA)?

  — How do the following relate or interact: the development of particle accelerators, the discovery of subatomic particles, and the revision of atomic theory?

- Students analyze natural and technological systems to interpret and explain their structure and dynamics.

  Examples:

  — Analyze the numerous steps involved in refining petroleum to obtain gasoline and a variety of additives for car engines.

  — Examine the production of hydroelectricity.

Applying

- Students describe the functioning of domestic, industrial, or medical technologies by identifying the scientific principles contained in their design.

  Examples:

  — What principles of physics are involved in the design and use of technologies related to computerized axial tomography (CAT scan) or magnetic resonance imaging (MRI)?

  — Describe the development of the aerospace industry and the modern airplane.

Teacher Notes

General Learning Outcome A	Specific Learning Outcome
Students will… Differentiate between science and technology, recognizing their strengths and limitations in furthering our understanding of the world, and appreciate the relationship between culture and technology.	**SLO A5:** Describe and explain disciplinary and interdisciplinary processes used to enable us to investigate and understand natural phenomena and develop technological solutions.

Suggestions for Instruction

Activating

Prior Knowledge Activity

- Brainstorm some topics in science and use a concept map to link disciplinary and interdisciplinary processes used to investigate and understand the topics.

  Examples:

  — cloning

  — living in space

  — time travel

  — forensics

Acquiring

Development of Concepts

- Students explain the roles of evidence, theories, and paradigms in the development of scientific knowledge, and discuss how major paradigm shifts can change scientific world views.

  Examples:

  — Explain how the realization that some acidic substances contain no hydrogen in their formula led to a revision of the Arrhenius theoretical definition of acids.

  — Discuss the radical change in thought process that must have accompanied the shifting of views of the Earth as flat and unchanging to round and changing.

  — Compare the evidence and theories of Lamarck and Darwin.

  — Discuss how the theory of plate tectonics explains the global distribution of mammals.

- Students identify and explain the importance of systems of scientific nomenclature and develop personal experience in using them, including communicating the results of a scientific endeavour, using appropriate linguistic modes and conventions.

  Examples:

  — Use geologic conventions from stratigraphy to explain the importance of specifying relative and absolute dating information when describing the location of a particular fossil.

  — Use the appropriate nomenclature to describe the chemical composition of solutions.

  — Use the correct species designation to compare similar organisms.

  — Describe enzyme function.

Applying

- Students identify and model the characteristics of peer review in the development of scientific knowledge.

  Examples:

  — Use rubrics to assess the research papers or laboratory reports of classmates.

  — Write a review of a scientific journal article.

  — Describe how the theory of evolution was refined by the contributions of different scientists.

  — Investigate how the lack of recognition or acceptance by peers resulted in the rejection of many scientific ideas (for example, the ideas of Mendel, Jenner, Galileo).

Suggestions for Teacher Learning Resources

Print Resources

Bedini, S.A. "Galileo and Scientific Instrumentation." *Reinterpreting Galileo*. Ed. W.A. Wallace. Washington, DC: Catholic U of America P, 1986.

Bent, H.A. "Uses of History in Teaching Chemistry." *Journal of Chemical Education* 54 (1977): 462-466.

Beyerchen, A.D. *Scientists under Hitler: Politics and the Physics Community in the Third Reich*. New Haven, CT: Yale UP, 1977.

Bleier, R. *Science and Gender*. New York, NY: Pergamon Press, 1984.

Brooke, J.H. *Science and Religion: Some Historical Perspectives*. Cambridge, MA: Cambridge UP, 1991.

Brouwer,W., and A. Singh, "Historical Approaches to Science Teaching." *Science Education* 21.4 (1983): 230-235.

Bruno, Leonard C. *Science and Technology Breakthroughs: From the Wheel to the World Wide Web*. 2 vols. Detroit, MI: U.X.L., 1998.

Brush, S.G., ed. *History of Physics: Selected Reprints*. College Park, MD: American Association of Physics Teachers, 1988.

Bush, D. *Science in English Poetry: A Historical Sketch*, 1590-1950. London, UK: Oxford UP, 1967.

Crowe, M.J. *Theories of the World from Antiquity to the Copernican Revolution*. New York, NY: Dover Publications, 1990.

Fat Man and Little Boy. Videocassette. Paramount, 1989.

Feynman, Richard. "Los Alamos from Below." *Surely You're Joking, Mr. Feynman!* New York, NY: W.W. Norton, 1985. 107-136.

Funkenstein, A. *Theology and the Scientific Imagination: From the Middle Ages to the Seventeenth Century*. Princeton, NJ: Princeton UP, 1986.

Gribbin, John R. *In Search of Schrodinger's Cat: Quantum Mechanics and Reality*. New York, NY: Bantam Books, 1985.

Keller, E.F. *Reflections on Gender and Science*. New Haven, CT: Yale UP, 1985.

Matthews, Michael R. *Science Teaching: The Role of History and Philosophy of Science*. New York, NY: Routledge, 1994.

Monastersky, Richard. "Scrambled Earth." *Science News* 145.15 (1994): 235-238.

Price, Derek John de Solla. *Science since Babylon*. New Haven, CT: Yale UP, 1975.

The Race for the Double Helix. Videocassette. BBC Horizon Series, 1974.

Sobel, Dava. *Galileo's Daughter: A Historical Memoir of Science, Faith, and Love*. New York, NY: Walker, 1999.

Stix, Gary. "Infamy and Honor at the Atomic Café." *Scientific American* 281.4 (Oct. 1999): 42-44.

Trefil, James, and Robert M. Hazen. "Thinking More about Entropy: Aging." *The Sciences: An Integrated Approach*. 3d ed. New York, NY: John Wiley, 2001. 94.

Watson, James. *The Double Helix*. New York, NY: Penguin, 1968.

White, L. *Medieval Technology and Social Change*. Oxford, UK: Oxford UP, 1962.

---. "Pumps and Pendula: Galileo and Technology." *Galileo Reappraised*. Ed. C.L. Golino. Berkeley, CA: U of California P, 1966.

Online Resources

Department of Geology, U of Toronto. 11 May 2005 <http://www.geology.utoronto.ca/>.

How Do Physicists Study Particles? European Organization for Nuclear Research. 11 May 2005 <http://public.web.cern.ch/Public/Content/Chapters/AboutCERN/HowStudyPrtcles/Accelerators/Accelerators-en.html>.

Protein Crystallography on the Web. School of Crystallography, Birkbeck College, U of London. 11 May 2005 <http://px.cryst.bbk.ac.uk>.

Teacher Notes