University of Alberta

A Contemporary Curriculum Development Model: A Case Study of the Development and Implementation of Alberta's Senior High Science Programs

by

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A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Education

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Dedication

To my father, Allan Wilhelms, and my grandfather, John Wilhelms, who instilled in me the love of, and value for, education.

Abstract

This study presents an analysis of the development and implementation of the current Alberta senior high science curriculum. It includes the development of a complex, multidimensional, dynamic model which is recursive in nature. This holistic portrayal may help us to better understand the complex dynamics of large-scale, contemporary curriculum reform and provide guidance to other jurisdictions facing change in science education towards an STS perspective. The model and its nested sub-models portray the interrelationships among four program components: programs of studies, resources, professional development and the consultation and communication process.

Acknowledgements

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CHAPTER 1 INTRODUCTION

The Context for Curriculum Reform

A knowledge explosion in science, developments in learning theory and the launching of Sputnik in 1957 combined to provide an overwhelming stimulus for science curriculum reform in the 1960s (Blades, 1994; Hart, 1990). Americans were afraid of 'falling behind' the Soviet Union so there was a call to reform science education to produce a more scientifically-based workforce and a scientifically literate citizenry (Fensham, 1988). Millions of dollars were spent on education to produce "alphabet soup science" curricula such as BSCS, PSSC, and CHEMStudy (Kyle, Shymansky & Alport, 1982). These programs were designed by scientists to stress the structure of the disciplines and the nature of science process. The primary goal of these science programs was academic preparation for further science study and the resource materials were designed to be "teacher-proof" (a complete resource package was handed over for teachers to use). Although these programs were designed for American students, Canadian provinces imported these programs with little or no modification (Connelly, Crocker & Kass, 1985).

In the 1970s, the science programs developed in the 1960s became the focus of evaluation: dissatisfaction and criticism followed. Despite the best intentions, there was little evidence from studies on the status of science education that classroom practice actually changed as a result of the curriculum reform efforts (Stake & Easley Jr., 1978; Weiss, 1978). The narrow focus on academic preparation was criticized for its exclusion of personal, societal and career goals. Textbooks were criticized for being highly theoretical with little relevance to students' lives (Yager, 1993).

In Canada, the results of the Science Council of Canada study of science education (Science Council of Canada, 1984) and the findings of the Canadian involvement in the Second International Science Study of the International Association for the Evaluation of Educational Achievement (Connelly, Crocker, & Kass, 1985, 1989) were published. One essential purpose of these studies was the assessment of attempts at science education curriculum reform in

Canadian science education (Blades, 1994). Both studies cited the need for reform in science education. Concurrently, awareness of environmental issues and the need for technologically literate citizens with an understanding of the implications of science were emerging as aspects of the technological and scientific activity that needed to be considered in the design of science curriculum.

The Canadian province of Alberta has been participating on the leading edge of Science/Technology/Society (STS) science education reform. Blades (1994) claims that to date this region has made one of the first and most sustained efforts in effecting a change in school science education towards an STS perspective. This has been a complex undertaking involving Alberta Education personnel, numerous committees, field validation teachers, consultants and administrators in the field validation and field validation inservices, approximately 4600 students in the field validation, and extensive consultation with science education stakeholders during the time period from 1985 to 1994. Analysis of the current Alberta senior high science curriculum development and implementation process and the development of a model which portrays the key components and their interrelationships may help us to better understand the complex dynamics of contemporary curriculum reform and provide guidance to other jurisdictions facing change in science education towards and STS perspective. To present such an analysis is the objective of my study.

The curriculum development process is complex and is grounded in a particular context. The development of the current Alberta senior high science programs is no exception. New challenges were continually arising throughout the development and implementation process. Some of these challenges were the inclusion of STS connections into the programs of study, the common design framework of the programs of study, the identification and development of a broad range of resources to support the implementation of the programs, the dynamics of the introduction and implementation of the proposed program changes by science teachers, and the complex consultative process used to determine the nature and needs of curricular reform. The development of the program was made even more challenging as the project was a large-scale, mandated curricular change that was the focus of considerable public and media attention.

Before I embark on a description and analysis of this curriculum development initiative, a brief description of the Alberta education system and the senior high science program structure is presented.

The Alberta educational system classifies grades 1-6 (Ages 6-12) as elementary school, grades 7-9 as junior high school and grades 10-12 as senior high school. In senior high academic science, the grade 10 courses are designated as 10-level courses, the grade 11 courses are designated as 20-level courses and the grade 12 courses are 30-level courses as shown in FIGURE 1.1. In senior high school students are allowed to take courses at a level other than their grade level. For example, a student may take 30-level courses in grade 11 or 20-level courses in grade 12. Accumulation of a certain number of credits (usually 3 or 5) earned with each passing grade (minimum of 50 %) in a high school course, combined with credit requirements in different subject areas, results in the achievement of a high school diploma.

In the previous senior high science program, students proceeded from Science 9 into one or more discipline courses: Biology 10, Chemistry 10 or Physics 10. From there students could take the subsequent discipline courses at the 20-level then at the 30-level. In the current senior high science program implemented in 1992, students proceed from Science 9 to a general Science 10. Then they take one or more of the discipline 20-level and 30-level courses or the general science stream, Science 20-30. A major change from the previous to the current senior high science program is the introduction of an academic general Science 20-30 stream. This stream is intended for students needing advanced academic credits in high school but who did not intend to pursue a science career. The discipline streams are intended for students who plan to study science at advanced levels. Another major change in the senior high science program is the time the student can spend taking science. A three credit course is equivalent to a one semester course (62.5 hours per course) and a five credit course is equivalent to a full year course (125 hours per

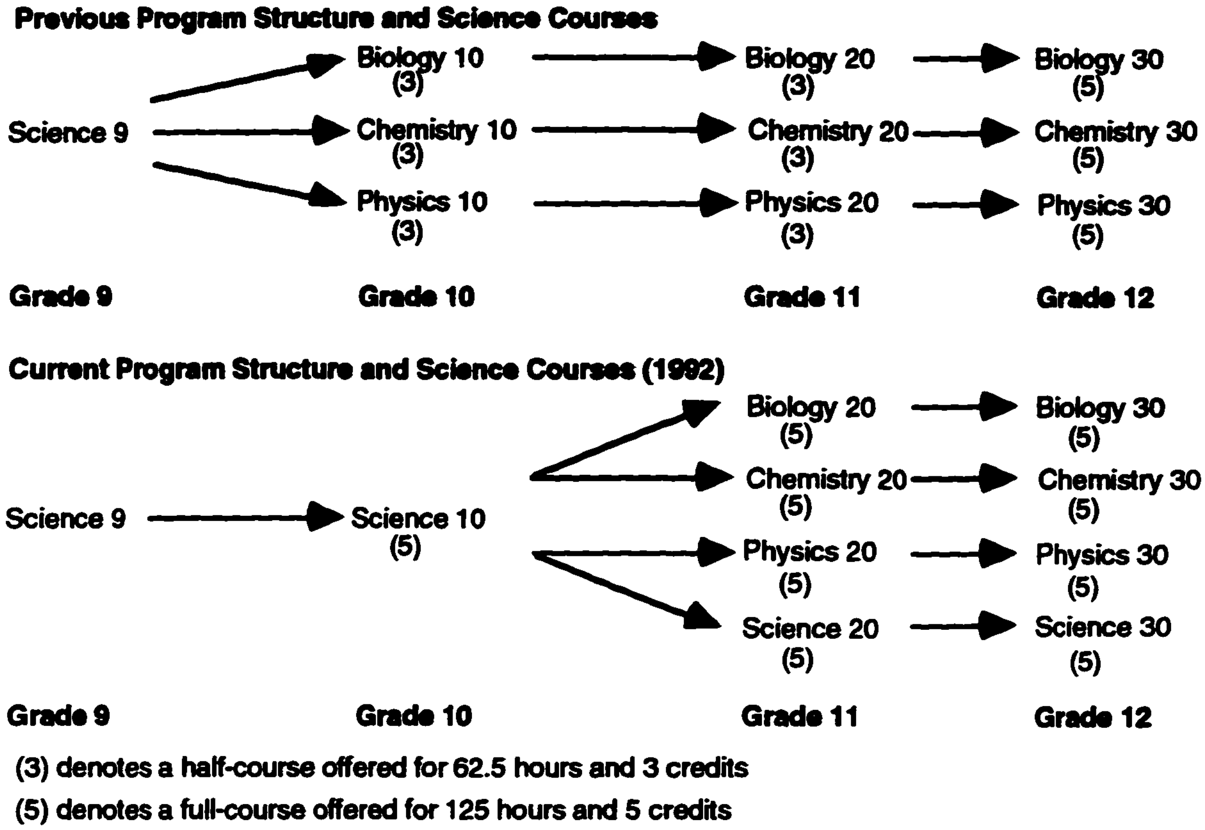

FIGURE 1.1 - Senior High Academic Science Program Structure

course). A student taking Science 10 plus one 20-30 course sequence would take an additional 125 hours of instruction compared to the similar course sequence in the previous senior high science program.

Major changes to the content of the programs were also introduced. Emphasis on scientific literacy, STS connections, nature of science, big interconnecting themes of science, the interdisciplinary nature of science, problem-solving skills, thinking skills, and research skills are some aspects of the changes in program content and focus. An account of how such complexity was developed as a part of the senior high science curriculum change is a major focus of this study.

Statement of the Problem

The purpose of this study is to examine the development and implementation planning of the revised Alberta senior high science programs for the purpose of identifying and describing the components and their interrelationships in the curriculum development process. This case study narrative is descriptive and interpretive as the story of the development of the programs of study for the current senior high science programs unfolds and the development of a conceptual framework for future curriculum planners is undertaken. In this case study, I intend to develop and present a contemporary curriculum development model of a complex, multidimensional, dynamic, large-scale, mandated curriculum change.

Guiding Questions

Question 1 - What are the characteristics of curriculum development in a complex, multidimensional, dynamic environment?

There are many ways in which this question can be addressed. For the purpose of my study, this broad question will be examined in the context of two sub-questions:

> **Question 1.1** - What are the interrelationships between the components of the curriculum development process?
>
> **Question 1.2** - How do the patterns of consultation and communication influence the shape of a complex, multidimensional, dynamic curriculum development model?

Research Design

I have chosen a descriptive and interpretive case study research design to tell the story of an extended curriculum development project; a complex and recursive process of consultation and development of the senior high science programs in Alberta. Data sources for my study include the Alberta Education documents related to this project (outlined in the timeline presented in Appendix C), personal recollections of formal and informal conversations with curriculum program consultants and field validation teachers, and interviews with members of the Alberta Education 'Science Team' (please see Definition of Terms). I was a participant in the development process, both as a member of the Science Team and as a teacher of the current senior high science programs. The data will be organized both chronologically and thematically to identify the components and influences on the curriculum development process. My goal is to propose a model which captures the essence of the curriculum development process. Since this model is expected to be complex, various aspects will be developed in terms of sub-models pertaining to each of the two sub-questions.

Definition of Terms

The following terms are used extensively in this study. A number of these terms are used in the curriculum literature and are open to multiple meanings and interpretations. Other terms are part of the local vocabulary of Alberta Education. These are described in accordance with their local meanings.

Alberta Education

"Alberta Education, a department of the Alberta government, carries out the provincial government's constitutional responsibility for education under the direction of the Minister of Education. The department administers legislation, regulations, policies relative to governance, funding and delivery of education in the province. The provincial government defines directions and sets goals for education programs, ensures equity in education financing, sets provincial standards for student achievement and teacher certification and assesses the results achieved by schools and school boards across the province" (Alberta Education, 1990d, p. 35).

Curriculum

There are numerous definitions of curriculum. Some of these will be discussed in Chapter 2. For the purpose of my study, I will refer to the "official curriculum" which appears in policy documents and/or guidelines prepared by the Alberta ministry of education. The official or mandated curriculum document for secondary school courses in Alberta is referred to as the program of studies. This is a legal document setting out the learner expectations for each course.

Curriculum development

Curriculum development in the context of this thesis, will refer to the development of programs of study, the identification and development of resources and professional development, all of which take place within a recursive consultation and communication process.

Design Framework

The design framework describes the components of a program of studies and their interrelationships and is the precursor to the development of a curriculum. The design framework for the current Alberta senior high science programs is described in more detail in Chapter 4.

Diploma Examinations

Diploma examinations are provincially developed examinations designed to assess student performance in the 30-level course learner expectations as outlined in the programs of study. The final grade in the course is a blended grade: 50% teacher-awarded mark and 50% diploma examination mark. Science 30, Biology 30, Chemistry 30 and Physics 30 are examples of diploma examination subjects.

Emphases

An emphasis is the purpose for learning a particular set of scientific concepts and is implicitly stated within the concepts, skills and attitudes outlined in the program of studies. It becomes more explicit in teaching as the content and context are blended. Three emphases found in the Alberta senior high science programs are nature of science, science and technology and science, technology and society.

Field Validation

Alberta Education generally conducts a field validation process, led by an inservice and implementation team, for any new curriculum that they develop. A field validation is the trial or a pilot phase of a new program designed to elicit feedback regarding programs of study and resources. It is conducted in selected schools across the province. Teachers, identified as field validation teachers, pilot the new curriculum and resources in their classrooms and provide Alberta Education with information on how the new programs and resources are working with students. The advice from teachers is used to improve the draft programs of study and any student or teacher resources that may be under development.

Model

A model is a representation of aspects of a theory. It aids comprehension and theory building. It is useful for economically organizing and explaining large amounts of data. A graphic model can be a picture, drawing, or diagram of some of the major components, and their interrelationships of the concept being described (Ornsten and Huckins, 1988, p. 283-284).

Program of Studies

In Alberta, the program of studies is the legal document that outlines what students are expected to learn in each subject. It contains a rationale and philosophy statement, general student learning expectations, specific student learning expectations, and a list of basic learning resources.

Program Thrusts

The program thrusts are teaching and assessment strategies intended to be implemented in the senior high science program. They include topics such as teaching for thinking, STS teaching strategies, controversial issues in the classroom, focus on research, performance assessment, technology and media in the classroom, cooperative learning, teaching for conceptual change, and teaching with gender balance. Sections of the Senior High Science Teacher Resource Manual (Alberta Education, 1991a) describe these program thrusts in more detail.

Round One of Curriculum Development for the Alberta Senior High Science Programs (1985-1990)

This period of development was characterized by the development of programs of study in consultation with internal committees, the Senior High Science Advisory Committee and the subject area sub-committees. Due to negative feedback from stakeholders in science education including the reduction of 20-level discipline course credits from 5 to 3 and difficulties with the completion of the custom developed textbook, this stage of development culminated in two one-year delays in implementation.

Round Two of Curriculum Development for the Alberta Senior High Science Programs (1990-1994)

This stage of development was characterized by major changes to the design framework of the programs of study, and increase in the discipline course credits from 3 to 5, extensive support resource identification and development extensive inservice and implementation plans and extensive consultation with stakeholder groups.

Science Team

The Science Team was a group of Alberta Education employees and teachers, seconded for a definite period of time from their school systems, who were responsible for the development and implementation of the new senior high science program. This team consisted of the program manager, program consultants for Science 10-20-30, Biology 20-30, Chemistry 20-30, and Physics 20-30, and inservice and implementation consultants. A list of the Science Team member positions with specific service details is presented in Appendix A.

Science, Technology and Society (STS) Connections

One of the major features of the new senior high science program in Alberta was the inclusion of a required science, technology and society (STS) component to serve as a learning context for students. This component is often referred to as the STS connections component of the programs of study because 'STS Connections' is the heading of the column in the programs of study. STS connections provide teachers with examples of appropriate science, technology and society contexts that could be used to develop the major concepts, skills and attitudes components of the program. Appendix D presents examples of the general learner and specific learner expectations related to the STS component of Science 10 and excerpts from Science 20-30 and Chemistry 20-30.

Senior High Science Courses/Programs

Science 10 is an integrated academic general science course that is the prerequisite to subsequent 20-level science courses both general science and discipline courses. Science 10 consists of four units of study titled (1) Energy from the Sun (2) Energy and Matter in Living Systems (3) Energy and Matter in Chemical Change and (4) Change and Energy.

Science 20-30 is an integrated general science program designed for the academic student. Science 20 consists of four units of study titled (1) The

Changing Earth, (2) Changes in Living Systems, (3) Chemical Changes and (4) Changes in Motion. Science 30 consists of four units of study titled (1) Living Systems Respond to Their Environment, (2) Chemistry in the Environment, (3) Electromagnetic Energy and (4) Energy and the Environment.

Biology 20-30, Chemistry 20-30, and Physics 20-30 are disciplinary science courses designed as prerequisites for advanced study. Biology 20 consists of four units of study titled (1) the Biosphere, (2) Cellular Matter and Energy Flows, (3) Matter and Energy Exchange in Ecosystems, and (4) Matter and Energy Exchange by the Human Organism. Biology 30 consists of four units of study titled (1) Systems Regulating Change in Human Organisms, (2) Reproduction and Development, (3) Cells, Chromosomes and DNA and (4) Change in Populations and Communities.

Chemistry 20 consists of four units of study titled (1) Matter as Solutions, Acids, Bases and Gases, (2) Quantitative Relationships in Chemical Changes, (3) Chemical Bonding in Matter and (4) the Diversity of Matter: An Introduction to Organic Chemistry. Chemistry 30 consists of three units of study titled (1) Thermochemical Changes, (2) Electrochemical Changes and (3) Equilibrium, Acids and Bases in Chemical Changes.

Physics 20 consists of four units of study titled (1) Kinematics and Dynamics, (2) Circular Motion and Gravitation, (3) Mechanical Waves, and (4) Light. Physics 30 consists of four units of study titled (1) Conservation Laws, (2) Electric Forces and Fields, (3) Magnetic Forces and Fields, and (4) Nature of Matter.

Senior High Science Inservice Modules

These 13 modules provide background, activity descriptions, overhead masters and references required for teachers to plan and offer a half-day inservice session on a variety of topics. Preliminary information regarding these modules is presented in Appendix E.

Senior High Science Video Series

This series consists of 15 programs to facilitate implementation and to support the curriculum of the current senior high science program. Programs 1 and 2 describe the intents and content of the programs and the continuity between junior and senior high science. Programs 3 to 5 are for inservice featuring teachers using strategies consistent with the intent of the curriculum. Programs 6 to 8 convey science concepts for students and program 9 demonstrates diversity of careers available. Programs 10 to 15 present short single concepts in chemistry, physics and biology for students. A detailed description of these videos is presented in Appendix E.

Teacher Inservice

In the context of this thesis, inservice is the term used to describe the professional development activities provided for field validation teachers. These inservice activities were designed to help prepare field validation teachers to implement the senior high science programs in their classrooms.

Teacher Resource Manual (TRM or Background, Exemplars and Resources) A TRM includes materials that help teachers prepare lessons, select teaching methods and select resources that are suited to the needs of their students. The TRMs for the Alberta senior high science program are: the *Senior High Science TRM, the Science 10 TRM, Background, Exemplars and Resources for Science 20-30, Background, Exemplars and Resources for Biology 20-30, Background, Exemplars and Resources for Chemistry 20-30, and Background, Exemplars and Resources for Physics 20-30.* The Table of Contents of the Senior High Science TRM is presented in Appendix E.

Themes

Themes are big interconnecting ideas and principles that transcend science discipline boundaries, and reflect the unity among the natural sciences. They form a framework for the Alberta senior high science program and provide continuity with other curriculum components. The major curriculum *themes* 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.

Delimitations

The discourse of the curriculum development project was delimited to the four specific strands of academic senior high science programs that were developed concurrently: Science 10-20-30, Biology 20-30, Chemistry 20-30 and Physics 20-30. The study describes the development of the senior high science program holistically. By that I mean my focus is the development of the programs as a whole since the development of one program influenced the development of other programs. However, the primary focus will be on the development of the Science 10-20-30 program as this is 'new' to the Alberta senior high science program.

The senior high science curriculum reform began in 1985. However, I have focused my study on the chronology of events which occurred since the Minister's announcement in January 1990 (Alberta Education, 1990a) which officially started Round 2 of the Alberta senior high science development process to the end of the 30-level field validation year, June 1994. An account of the earlier development phase (Round 1 - 1985 to 1990) is presented in Blades, 1994. Circumstances or events that occurred prior to the Minister's announcement will be included if they directly influenced the curriculum development process in 1990-1994.

As noted earlier, this curriculum development project is complex in its scope. I will discuss but not emphasize the political aspects (discussed in Blades, 1994), the inservice component (discussed in Romanyshyn, 1996), and the implementation of the science programs (discussed in Shrum, 1996).

Assumptions, Limitations and Validity Considerations

Review of numerous official and unofficial Alberta Education documents associated with the project provided a timeline of events and useful information regarding the project. I have assumed that the documents accurately reflect the events as they occurred. Interviews with the program manager and an inservice and implementation consultant were used to validate my interpretation of documents. My assumption here is that the memory and perceptions of these members of the Science Team are relevant reconstructions to yield authenticity of interpretation. It is difficult to look back on such an extensive process and accurately recall one's initial perceptions as the project began. The time lag between the actual project and the telling of the story within this study posed the challenge of accurate reconstruction of thoughts at the time. Although details of the process are most certainly forgotten, I believe the major events and important specifics are vivid in the memory of Science Team members. Although each person interpreted specific events or processes differently, consensus regarding components of the model itself was achieved.

The study is also limited by my interpretation of events. The analysis of events reflects my personal involvement with the Science Team and my assumptions and world view. However, it is also because of my personal involvement that I have described the process in a contextualized way. Combining recollections of Science Team members, my own recollections and the extensive documentation yields a triangulated and multiperspective account of the Alberta senior high science curriculum development process.

Ethical Considerations

To assure the ethical considerations associated with my study were met, I obtained written permission from Alberta Education (Appendix B) to use the following data sources:

- official and unofficial documents relevant to the senior high science curriculum development project (includes such items as planning documents, needs assessment summaries, committee minutes, mailout packages, and field validation reports.)

Before the interviews with my Science Team colleagues was undertaken, the participants were provided with a letter requesting participation. The letter clearly defined the participation expectations and the intended use of the interview material gathered. A consent form accompanying the letter granting me permission to videotape and audio tape the interview and to use their interview comments in this study was signed and submitted to me by the interview participants. A copy of the letter and consent form are presented in Appendix F.

Personal Ground

I graduated with a Bachelor of Science Degree from the University of Alberta in April, 1985. I continued my studies with the Faculty of Education completing the requirements for a teaching certificate in August, 1986. I taught junior and senior high science for two years at a small rural high school. Subsequently, I taught at a large rural high school just outside Edmonton from September of 1989 until I was seconded to Alberta Education in February of 1991, seven months prior to the field validation of Science 10.

Upon reflection I realize that prior to my secondment, I had taught my students the way I had been taught myself. I focused on objectives and outcomes. I did not explicitly make science relevant to students in my classes. I was a technician who was there to provide 'the' answers. If I could not answer a question, I would make sure that I had the 'right' answer for them the next day. I viewed 'knowledge as truth'. I lectured to students as if they had no prior knowledge or background experience in science. The experiments we performed were validation labs, reconfirming established knowledge. If the students asked "Why are we learning this stuff?", my standard response was "to prepare you for University". I enjoyed learning and teaching science but science was abstract and theoretical to me. I taught science as if it consisted of distinct disciplines because I had never made connections between scientific disciplines. I was firmly entrenched in the 'positivistic paradigm' (Kuhn, 1970).

In the fall of 1990, I attended an information session regarding the changes in high school science curricula. I remember very vividly sitting in a classroom at Northern Alberta Institute of Technology (NAIT), listening to the presentation (the rationale) for changing the curricula. The changes, particularly in biology the subject I was currently teaching, seemed totally illogical to me. My opinion, and that of several colleagues, was that there was no rational reason to separate units from Biology 30, a course on human physiology, into two levels, (Biology 20 and 30) and add genetics and ecology to the 30-level as proposed in the new science programs. I remember being so overwhelmed and so close to tears that I could not respond to the Biology Program Consultant's request for comments for fear of losing my composure. This was my first experience with the proposed changes to new senior high science programs.

How did I end up working for Alberta Education Curriculum Branch? To this day I am still not certain. The secondment was approved by the Superintendent of my School Division and by my Principal before I was contacted for an interview (I found out later that this was the normal top-down communication process of Alberta Education). For reasons that still remain a mystery to me, I was "invited in" to become an Inservice and Implementation Consultant with the Science Team. My primary responsibility would be to identify resources for the new senior high science programs. I felt honored to be selected for the position yet nervous about the journey ahead.

My first task at Alberta Education was to immerse myself in the background documents for the senior high science programs entitled: *STS Science Education: Unifying the Goals of Science Education* (Jenkins, 1990), *Teaching Thinking: Enhancing Learning* (Alberta Education, 1990f) and *Focus on Research: A Guide to Developing Students' Research Skills* (Alberta Education, 1990g). These documents outlined the framework for some of the program thrusts which were incorporated into the programs of study, teacher resource manual development, senior high science inservice module development and inservice planning. My teacher preparation preceded the publication of these documents so they were unfamiliar to me. As I read through these documents, I remember feeling overwhelmed (again). *STS Science Education: Unifying the Goals of Science Education* (Jenkins, 1990) discussed science, technology and society connections and making science relevant to students. Prior to reading this document I did not understand the nature of the STS movement. *STS Science Education* presented a very different view of science teaching to the one I held. As a result, I started to question the way I had taught science and began to see a need for change in my teaching strategies. *Teaching Thinking: Enhancing Learning* (Alberta Education, 1990f) started me thinking about thinking. I am still not sure why I had never considered the need to explicitly develop critical problem-solving or decision-making skills with students, but I know I did not explicitly plan for it in my lessons. I guess I assumed that it was something that just happened when you taught science. *Focus on Research* (Alberta Education, 1990g) is a monograph that focuses on students learning how to use library resources to gather, process and share information. This was a skill that I had tried to integrate into my teaching but this resource provided an explicit framework that had been lacking in the projects I had been assigning to my students. As I read these documents I remember feeling pretty inept as a science teacher.

My immediate supervisor and valued colleague helped me realize that my experience was not atypical of science teachers and although I could not change the way I had taught science in the past, I could change the way I would teach science in the future. I could also provide support and empathy for other teachers who would face similar frustrations to those that I had faced. This would become part of my job as an Inservice and Implementation Consultant. In addition to identifying resources for the new programs, within a few months we had to consolidate and edit the *Senior High Science Teacher Resource Manual* (Alberta Education, 1991a), the *Science 10 Teacher Resource Manual* (Alberta Education, 1991b), the *Senior High Science Inservice Modules*, (Alberta Education, 1991e) and plan the Science 10 Inservice for the field validation teachers who would be teaching Science 10 in September, 1991. In May 1991, my secondment was renewed for another year so I continued working with the Science Team.

In May 1992, I began a Master's Degree program at the University of Alberta. The first courses of my program were titled "Curriculum Development" and "Current Curriculum Development. As we reviewed literature on curriculum development models, I concluded that the models we discussed in class did not adequately represent the development process with which I had been involved at Alberta Education. This was where my interest in curriculum development theory began. Upon returning to the classroom in September, 1992, I faced the realities of attempting to 'enact' an 'intended' curriculum and viewed the curriculum development process from yet another perspective.

Since 1993, I have worked part-time at Student Evaluation Branch assisting with the development of the Science 30 Diploma Exams. Focusing so intently on evaluation caused me to view the curriculum development process from a third perspective. These multiple perspectives gave me additional insight into the complexity of the curriculum development process. It is my hope that insights from this thesis and the curriculum development model, which is presented in Chapter 5, will be useful to other science curriculum developers faced with large-scale mandated curriculum change toward an STS perspective.

Related Studies

Several studies that examine different facets of the Alberta secondary science curriculum development and implementation (grades 7-12) have been completed in recent years.

The first of these studies considers the implementation of the STS component of the new Alberta junior high science curriculum.

- Roscoe, K (1993). STS in the Classroom: An Interpretive Study - unpublished Ph.D. Dissertation - Edmonton, Alberta: University of Alberta.

The three studies and one paper, listed below, examine aspects of the Alberta senior high science curriculum development and implementation. David Blades worked at Alberta Education while completing his Ph.D. at the University of Alberta. The remaining documents are authored by former Alberta Education Science Team members:

- Blades, D. (1994). Power and possibilities for change in science education curriculum - Discourse. Unpublished Ph.D. Dissertation, University of Alberta, Edmonton, Alberta.

- Panwar, R. & Hoddinott, J. (1995). The influence of academic scientists and technologists on Alberta's secondary science curriculum policy and programme. International Journal of Science Education, Vol. 17(4), 505-518.

- Romanyshyn, B. (1996). Teachers and curriculum change: Examining inservice program implementation. Unpublished Masters Thesis, University of Alberta, Edmonton, Alberta.

- Shrum, S. (1996) How the STS component of the new Alberta senior high science curriculum (Science 10) is being implemented in the classroom. Unpublished Masters Thesis, University of Alberta, Edmonton, Alberta.

While the studies listed above examine aspects of the politics of curriculum change, teacher inservice and the implementation of the new science programs in the classroom, my study examines the curriculum development process of a large-scale, mandated curriculum change in the senior high science program in the province of Alberta.

Significance

There are few studies in the curriculum literature that are concerned with large-scale curriculum development. This study attempts to inform us about what it is like to be involved in a large-scale curriculum development project. This study is significant in that it can help curriculum developers who might be experiencing a similar curriculum change to reflect on the Alberta senior high science curriculum development experience. It contributes to contemporary curriculum field theory and scholarship an example of the complex, multidimensional, and dynamic nature of contemporary curriculum development.

Outline of the Study

Chapter 2 presents related literature about curriculum development, curriculum development models and managing change. Chapter 3 presents the global and Canadian context for the Alberta senior high science curriculum development project. Chapter 4 presents a description of the Alberta senior high science curriculum development process. Chapter 5 presents the model and sub-models I have designed to represent the Alberta senior high science curriculum development process. Chapter 6 presents a summary of the implications of this study, the limitations of this study as well as some questions and directions for further research.

CHAPTER 2 LITERATURE REVIEW

What is curriculum?

The term 'curriculum' has multiple interpretations and connotations, therefore it is important to define how the term will be used in the context of this thesis. Jackson (1992) notes that there are two major kinds of writings are present about curriculum in the annual volumes of the *Educational Index*. One is about the installation or evaluation of specific subjects or topics within the curriculum of a particular school or set of schools. Much of this writing is detailed and technical and is not directly related to this study. The other kind of writing deals with construction of general theories and principles of curriculum development or broad perspectives on the curriculum as a whole or on the status of curriculum as a field of study. This literature is more relevant to my study. The purpose of this chapter is to present some background related to curriculum and curriculum development as it relates to the development of the Alberta senior high science programs. It includes a discussion of definitions of curriculum, curriculum perspectives, curriculum ideologies, curriculum organization, an outline of various curriculum development models, and management of curriculum change. Except when directly pertinent to my study, I will not be discussing evaluation of curriculum nor will I get involved in a discussion of the relative merits of particular perspectives, ideologies or models.

How is the term 'curriculum' defined?

There are a multitude of definitions of curriculum but most fall somewhere between two ends of a continuum. One pole is that a curriculum can be defined as a plan for action, or a written document, which includes strategies for achieving desired goals or ends. For example, Saylor (1981, p. 10) defines curriculum as "a plan for providing sets of learning opportunities for persons to be educated." Pratt (1980, p. 4) states, "curriculum is an organized set of formal educational and/or training intentions." Wiles and Bondi (1993, p. 135) view curriculum as "a plan for learning [whereby] objectives determine what learning is important."

The other pole is rooted in Dewey's (1938) definition of experience and education, that curriculum can be defined as dealing with all the experiences children have under the guidance of teachers. This view considers almost anything in school, even outside of school (as long as it is planned) as part of the curriculum. Other writers who subscribe to this definition include Shepard and Ragan (1985, pp. 3-4) who state that the "curriculum consists of the ongoing experiences of children under the guidance of the school", and Eisner (1974, p. 41) who describes the curriculum as "a program [the school] offers to its students." It consists of a "preplanned series of educational hurdles" and "an entire range of experiences a child has within the school." Hass (1983, p. 41), takes the other view that "curriculum is all of the experiences that individuals have in a program of education...which is planned in terms of ... theory and research or past and present professional practice." Other definitions fall somewhere in between these two poles.

Posner (1995) discusses five concurrent curricula: the official, the operational, the hidden, the null, and the extra curriculum. The *official curriculum* is a document which provides a basis for teachers to plan lessons and evaluate students. The *operational curriculum* consists of what is actually taught by the teacher and how its importance is communicated to the student. The *hidden curriculum* concerns issues of gender, class and race, authority and school knowledge. This may include lessons about sex roles, appropriate behavior, which children can succeed at which tasks, who makes decisions, and what kinds of knowledge are legitimate (Giroux & Purple, 1983). The *null curriculum* (Eisner, 1994) consists of those subjects matters not taught. The *extra curriculum* comprises all those planned experiences outside the school subjects. Although all five aspects of curricula contribute to the education of students, for the purposes of this study, the Alberta senior high science programs of study will be considered synonymous to the *official curriculum* described above.

What are the dominant perspectives of curricular content?

There are a multiplicity of ways of looking at curricular content. These views are affected by views of knowledge, the learner, the teacher, the role of the curriculum developer and the social conditions outside the school. Historically in curriculum literature, Dewey (1899) and Bobbitt (1918) describe two perspectives on the role of schooling: the traditionalists (conservatives) who tend to believe that schools should stay basically the same, and the reformers (progressives) who are committed to changing the educational system.

It is no surprise that those who are committed to change are not likely to share a unified vision. Hence other perspectives have evolved. Each of these perspectives has a different influence on the purpose, content, method, organization and evaluation of curriculum (McNeil, 1977). Schubert (1986) speaks of three categories: intellectual traditionalist, the social behaviorist, and the experientialist. McNeil (1977) outlines four conceptions of curriculum: humanistic, social reconstructionist, technologist and academic. Kliebard (1987) looks at four interest groups: humanists, developmentalists, social efficiency educators, and social meliorists. Eisner and Vallance (1974) outline five orientations: cognitive process, technological, self-actualization, social reconstructionist and academic rationalist. The consensus seems to be that there are fewer than six independent perspectives and that there is a substantive thrust for each of these perspectives. The traditionalists value an enduring core of content in schooling. The reformers are divided into different schools of thought: those who think schools should serve the individual by contributing to personal development to free his or her potential, those who think schools should serve as an agent of social reform and those who do not view these as mutually exclusive. The technological position seems less concerned about where schools are going or should go than on how effectively or efficiently they get there. Other positions are essentially modifications of these perspectives. Due to the nature of consultation and the influence that the consultation had on the development process, the Alberta senior high science programs reflect several of these perspectives.

Curriculum and Ideology

Perspective is influenced by ideology. Curriculum ideologies can be characterized as beliefs about what schools should teach, for what ends and for what reasons. Ideologies manifest themselves in the kinds of language that imply or suggest, rather than state explicitly, what is educationally important and what the school's curricula should address. Alberta is a multicultural province. As such, the educational system in general reflects a variety of ideological positions.

Eisner (1992) states that there is no single ideology that directs education. Ideological positions exist in a state of tension or conflict. In pluralistic societies, competing views of what schools should teach and for what ends can emerge during the curriculum development process. Regardless of how powerful an ideological view may be in any individual's or even group's orientation to the world, it is seldom adequate to determine what the school curriculum will be in a democratic society. There is a political process that inevitably must be employed to move from ideological commitment to practical action. When a society is characterized by value plurality and when the political strength of groups is comparable, the process must lead to compromises. As a result, the public school curriculum seldom reflects a pure form of any single ideological position, if a "pure" form exists. Indeed, the more heterogeneous the community, the less likely there will be ideological uniformity in schooling. Schools and curriculum do not remain static. As social and economic conditions change, a school's political climate is altered. It becomes necessary to accommodate these new conditions.

Eisner (1992) describes six prominent ideologies that direct education: religious orthodoxy, rational humanism, progressivism, critical theory, reconceptualism, and cognitive pluralism. Each of these ideologies is summarized below.

All **religious orthodox ideologies** share in the belief in God and the importance of God's message in defining the content, aims and conditions of educational practice. For example, one aim of Roman Catholic schools is to induct children into the Roman Catholic church. Religion classes and participation in religious celebrations are mandatory for students attending these schools. The impact of the beliefs of the religion also extend into other curricular topics such as sex education and evolution.

Rational humanism holds that the universe in which we live can be understood through rational methods (the existence of truth), that knowledge is a human construction, and that content is not to be construed as memorizing facts but as the development of a critical understanding of the values and premises that underlie important human works. The implementation of rational humanism is not widespread in schools. In part this may be because standardized assessment, which is prevalent in schools, is not consistent with an orientation to educational attainment that is dedicated to reason, rationality, and extended explanation.

Progressivism in education has two related but distinguishable streams. One of these was rooted in the nature of human experience and the development of intelligence, the other in social reform. Progressivism flourished under conditions that were right for educational change. It was no longer appropriate to regard the child as a passive receptacle to be filled with curriculum content. Mind and emotion could not be regarded as independent since how children felt about what they studied influenced how they thought about what they studied. Curriculum could no longer be thought of as a static body of content, created in administrative offices and handed down to the teachers. Progressivists believe that the curriculum should be problem-centered with the goal of cultivating unique talents. The teacher needs to start where the child is, create problematic situations then enable the child to stretch intellectually. Optimally, teachers would play a fundamental role in the development of the in-context curriculum.

Critical theory is not an ideology in the same sense as religious orthodoxy, rational humanism and progressivism. In general, critical theorists have not defined the aims, content and methods of education. Critical theory is an approach to the study of schools and society that has as its main function the revelation of the tacit values that underlie the enterprise. The approach emphasizes "critical reflection" on one's own "concrete situation" and requires "dialogue" in which teacher and student are "critical coinvestigators." Children are taught to ask of practices and policies in schooling and elsewhere, Whose interests are being served? A curriculum which promotes development of a complex view of controversial issues and asks students to examine their own value structure would have some of the features a critical theorist would applaud. Critical theorists are often more interested in displaying the shortcomings of schooling - raising consciousness - than providing models toward which the schools should aspire.

Reconceptualists view schools as a place for learning how to live rather than a place to learn how to earn a living. They believe that schools that intend to prepare students for life mislead when they convey to them that all problems have solutions and all questions have (correct) answers. Reconceptualists believe that what is missing from schools is a deep respect for personal purpose, lived experience, the life of imagination, and those forms of understanding that resist dissection and measurement. They believe that what is wrong with schools is their industrialized format, their mechanistic attitudes toward students, their indifference to personal experience and their emphasis on the instrumental and the out of reach. Reconceptualists believe that educators should try to understand the nature of the child's experience. In other words, educators need to change from a behavioristic to a phenomenological attitude. Reconceptualization requires educators to practice a non prescriptive, nonstandard approach to teaching. In an era of accountability, it is difficult for the major tenets of reconceptualization to take a stronghold and have a significant impact on schools.

Cognitive pluralism is a conception that emphasizes multiple ways of knowing. One distinctive feature of human being's is the capacity to create and manipulate symbols. Symbols are played out in mathematics, music, literature, science, dance, and visual arts, or any area of human life in which action or form is used to give expression or to represent experience or intention. Language is only one of the means through which the private, personal life of the individual is given a public presence. Symbol systems make it possible to 'stabilize' thought, feelings, or ideas and by transforming these symbols from private to public, communication is made possible. From communication, one derives meaning. However, meaning is both constrained and made possible by the features of a particular symbol system. Since the quest for meaning is part of human nature, cognitive pluralists believe that the ability to represent or recover meaning in the various forms in which it can be experienced should be a primary aim of schooling.

Each of the curricular ideologies described above has different degrees of implementability. Examples of religious orthodoxy and rational humanism can be found in schools. However, examples of the other ideological positions are more difficult to find. Of the remaining ideologies, progressivism is more prevalent than cognitive pluralism, critical theory, or reconceptualism as programs to implement cognitive pluralism are scarce and the latter are more attitudinal, than practical in nature. Yet ideologies provide a framework for curricular decision-making. These decisions influence deliberations about what the curriculum should become and what schools should be. As is the case with the perspectives of curriculum discussed earlier, a curriculum development project in a multicultural province such as Alberta which incorporates a high level of consultation in the development process is certain to reflect a variety of ideological positions. Perhaps, in today's milieu, there is a need for another curriculum ideology. One that is more complex, more diverse, more inclusive and incorporates the multicultural nature of many communities.

Curriculum Organization

The word "organize" means "to form as or into a whole consisting of interdependent or coordinated parts" (Random House, 1984, p. 937). The "parts in this case are elements of the curriculum. Posner (1995) states that the term "curriculum organization" can be used at different levels of specificity (macro and micro levels of organization) with at least two dimensions (vertical and horizontal dimensions). The broadest level of specificity (macro) refers to relations between educational levels, such as elementary and secondary or between programs, such as vocational and general programs. The most specific level (micro) refers to the relationship between particular concepts, facts, or skills within lessons. There are many levels of specificity between these two extremes. The two dimensions of curriculum organization are horizontal and vertical. If educational events occur along a timeline, the horizontal dimension refers to events that occur within the same time frame and the vertical dimension refers to events that occur subsequent to one another. The horizontal dimension describes scope of the content within a course or between courses at the same level (e.g., depth of coverage of acid-base chemistry in Science 30 and Chemistry 30). Issues related to the horizontal dimension include: Are there necessary corequisites (e.g., mathematics)? Is there a correlation of content taught in subjects which occur concurrently(e.g., environmental issues in Social Studies 20 and Biology 20)? The vertical dimension describes sequencing of content. This sequencing may be within a particular course (e.g., Unit 1-4) or between subsequent courses (e.g., Science 10-20-30). Issues related to the vertical dimension include: Is there a need for prerequisites? Are there ways of providing continuity between topics or courses (e.g., themes)? Is the content built on previous learning? As you can see these dimensions can be discussed at different levels of specificity (macro or micro levels of organization).

Organizational Principles

An organizational principle states the basis or reason for organizing a curriculum in a particular way. Posner (1995) states that a principle of vertical organization describes the reason for ordering or sequencing curriculum elements in a particular manner. A principle of horizontal organization describes why the curriculum presents certain elements in conjunction, or why the curriculum is organized around a particular element. One simple way of categorizing organizational principles is to use Schwab's four commonplaces: subject matter, the learner, the teacher and the milieu. Most curricula are organized around only one of the four commonplaces and most often this commonplace is subject matter. Subject matter tends to be organized the way the disciplines themselves are organized. For example, science tends to be organized around subject disciplines such as biology, chemistry or physics. A curriculum centered on the learner, would focus on the characteristics of learners and the way they learn. The characteristics of learners relevant to curriculum organization include their interests, problems, needs, previous experiences, preconceptions and developmental levels. These characteristics give the curriculum a starting point. For example, if a student lives near a coal-burning power plant a science teacher could relate concepts of energy production and environmental impact to a situation that is meaningful to the student. Curriculum organization decisions may also be based on factors related to a teacher's personal characteristics, the tasks a teacher faces or the teacher's interests and strengths. For example, a Science 30 teacher whose background is primarily biology may focus more time and attention on the biology unit rather than on the physics unit. Milieu refers to the social, economic, political, physical and organizational contexts in which education occurs and all of which may affect curriculum organization. However, these contexts tend to function more like influences on, rather than principles of organization.

The Alberta senior high science programs of study are organized around subject matter. However the *Senior High Science Teacher Resource Manual* (Alberta Education, 1991a) outlines a variety of teaching strategies whereby the curriculum may be organized around the other commonplaces described by Schwab. The table of contents of the Senior High Science Teacher Resource Manual is presented in Appendix E.

Content Structures

Content may be configured in a variety of ways depending on the degree of horizontal and vertical organization. FIGURE 2.1 presents a representation of these content structures. At one end of a continuum is the organization of content as discrete or independent topics. Each program or course would be self-sufficient and unrelated to other programs or courses. An example of this structure would be the television program *Barney*. Each program must be independent since there is no guarantee that the child has seen any other program. At the other end of the continuum is the organization of content as linear concepts or skills. Each concept or skill requires the mastery of the concept or skill immediately preceding it. An example of this structure is Mastery Learning (Bloom, 1971). One configuration which exists between these two extremes is a hierarchical or pyramidal configuration. This configuration includes multiple and perhaps unrelated concepts or skills which are needed for learning subsequent concepts or skills. An example of this configuration is Gagne's elementary science curriculum, *Science: A Process Approach* developed under the aegis of the American Academy for the Advancement of Science (AAAS, 1967). Another configuration between the two extremes is Bruner's spiral curriculum. This configuration is rooted in Piaget's ideas of cognitive development. Students progress through stages of cognitive growth at different levels so concepts should be repeated at higher levels of sophistication and abstraction in subsequent courses. This configuration forms the basis for the curriculum *Man: A Course of Studies* (Curriculum Development Associates, 1972). Examples of each of these content structures could be drawn from the Alberta senior high science programs. However, in general, the content structure would most closely resemble Bruner's spiral curriculum (Bruner, 1960). For example, the themes are revisited through each program at each level. Another example is the topic of acids and bases is introduced in Unit 3 of Science 10. Each subsequent dealing with the topic, such as in Science 20 unit 3 and Science 30 unit 2, builds on previous learning as students move from the 'iconic' mode to the 'symbolic' mode.

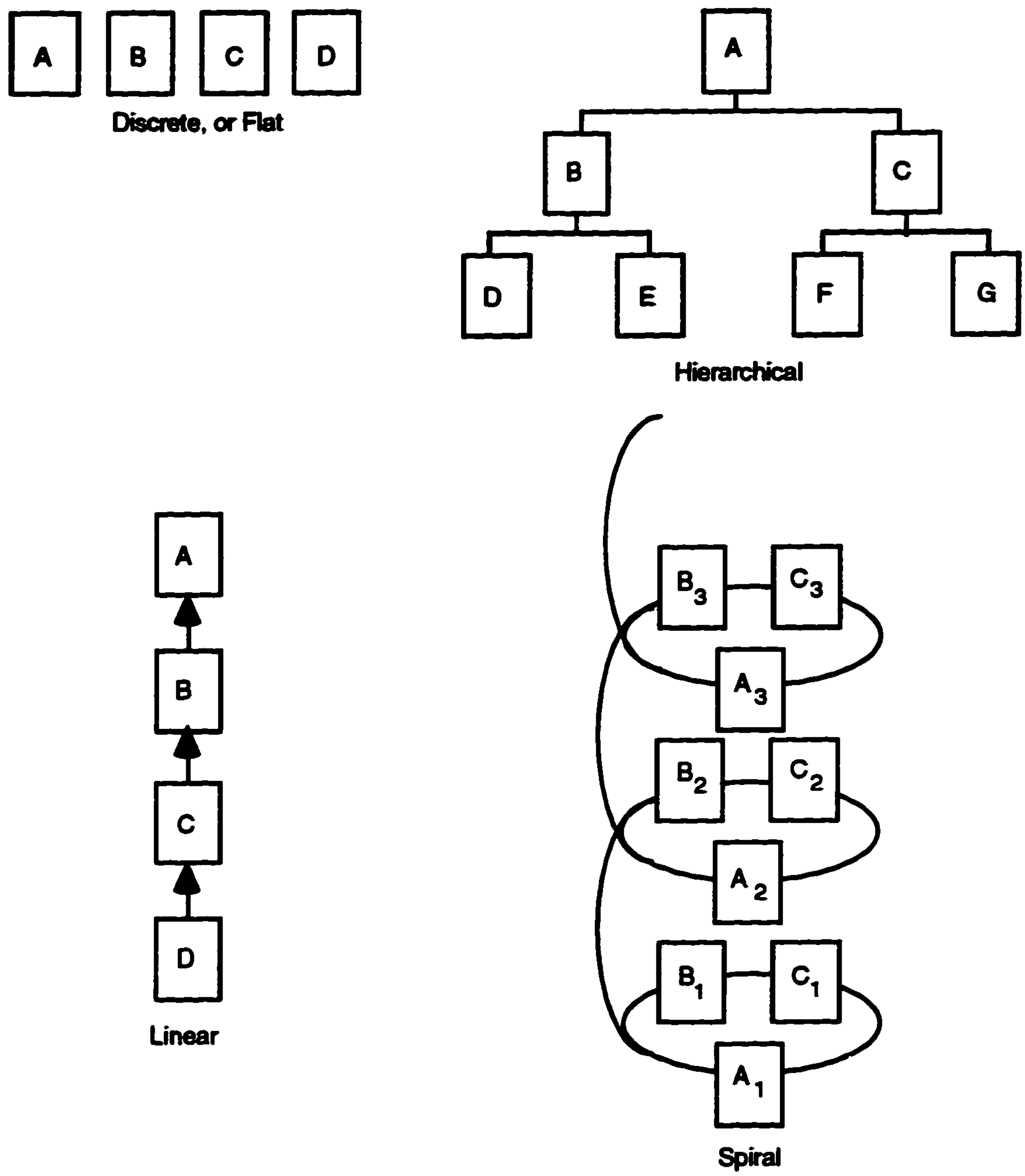

FIGURE 2.1 Content Structures (modified from Posner, 1995, p.127)

Media Structures

When curriculum is defined more broadly as including resources as well as the programs of study, curriculum may refer to the ways media, instructional activities, methods, and materials, relate to particular objectives. These "media" may be structured in different ways. FIGURE 2.2 presents a representation of media structures. A parallel structure may be exemplified by the text and laboratory manual in the *Chemical Bond Approach Project*. The two may reinforce each other but represent essentially separate courses. Rather than integrating the text and laboratory manual together, the teacher has the freedom to move back and forth between the two resources (Goodlad, 1964). A convergent structure assumes that different media, simulations, role plays, videos, print materials or other media, are different modes to accomplish the same objective. This is based on the assumption that there is no one way to achieve an objective and that students differ in their ability to learn from one medium. M:ACOS exemplifies a convergent structure. A divergent structure assumes that one 'media' may lead to a diverse set of learning outcomes. Project-centered or problem-centered curricula (e.g., the magazine Foxfire) often have this media structure. A mixed curriculum capitalizes on the strengths of several activities and methods to teach certain content but focuses all activities on a common objective. If taken as a whole, that is to say the Alberta senior high science programs of study taken together with the breadth of resources (basic, support, teacher and other), the package would represent an example of the mixed structure. The objectives are outlined in the programs of study but the activity or method used to achieve the objective may be attained through a variety of resources such as print materials, videos, computer programs, laser discs or role playing activities.

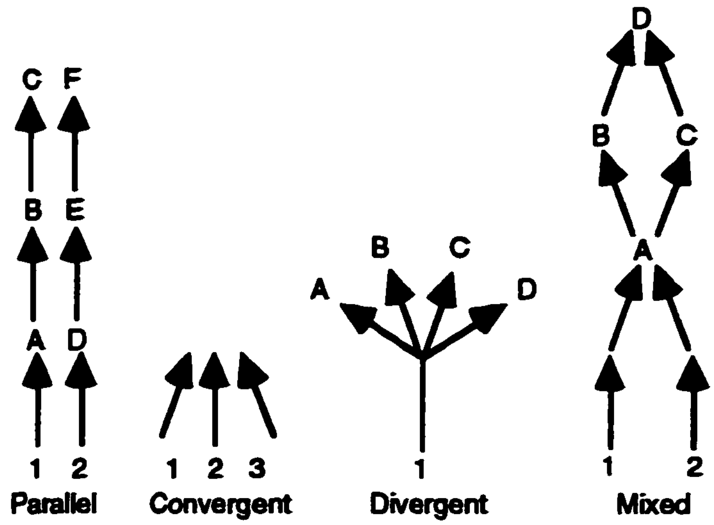

FIGURE 2.2 Media Structures (modified from Posner, 1995, p.128)

Approaches to Organization

Posner (1995) claims that there are three approaches to organizing a curriculum: top-down, bottom-up, and project. The top-down approach organizes the curriculum around fundamental concepts, themes, or principles. An understanding of these fundamental concepts allows the student to develop the ability to derive particular facts and applications. This approach has a hypothetical-deductive epistemological foundation (Popper, 1959). The fundamental ideas or "overarching themes" which form the substantive structure of the disciplines provide the organizational principle for curriculum development. This approach is exemplified in the Biological Sciences Curriculum Study (BSCS), PSSC and M:ACOS. The bottom-up view assumes that the most important determinant of learning is the possession of prerequisite skills. This approach has an inductive epistemological foundation. The responsibility of the curriculum developer is to organize the learning objectives into a series of small enough steps, and with no missing prerequisites, that the learners never falter (Gagne, 1970). This approach is exemplified in Science: A Process Approach. The project approach organizes curricula around student activities planned together by the student and the teacher. It is rooted in the progressive educational movement. The organizing principle is the scientific method which consists of recurrent cycles of thought-action-reflection. This approach is exemplified by the Foxfire program (Wiggington, 1985). The Foxfire program began as a magazine called Foxfire which was written, illustrated and distributed by students.

Models of Curriculum Development

Models can help us to conceptualize a process by making explicit certain principles and procedures (Oliva, 1992). I will describe several models of curriculum development which have been influential over the years and which will be used as a framework for analysis of the model I present in Chapter 5 to portray the development of the Alberta senior high science programs. The models in this chapter are discussed in the context of what the model brings to the discussion of curriculum development.

The Tyler Rationale

The Tyler Rationale is perhaps the most influential curriculum development model of the twentieth century. In 1949, Tyler published a monograph *Basic Principles of Curriculum and Instruction*. He refers to this monograph as a "rationale" and cautions that "it is not a manual for curriculum construction since it does not describe and outline in detail the steps to be taken by a given school or college that seeks to build a curriculum," but rather, it is a way of "viewing, analyzing, and interpreting" the program of an educational institution (Tyler, 1949). Although Tyler denies that his rationale is a method to be followed step-by-step, it has been interpreted and followed as such by many curriculum developers (Walker & Soltis, 1986; Posner, 1988).

Tyler (1949) states that curriculum development should address four fundamental questions:

1. What educational purposes should the school seek to attain?
2. What educational experiences can be provided that are likely to attain these purposes?
3. How can these educational experiences be effectively organized?
4. How can we determine whether these purposes are being attained?

In other words, the key features of Tyler's model are to state the objectives, select the learning activities, organize the learning activities and develop a means of evaluation. It is a deductive model in that it starts with identifying general goals and moves to organization of more specific learning experiences. Tyler's rationale concentrates on the how of curriculum development rather than the what of the curriculum itself. Tyler's model has provided the developmental sequence for innumerable local, regional and international curricula, including those of Alberta Education.

Taba's Model

Taba (1962) refined Tyler's model by adding three steps. Like Tyler's model (at least the way his model has been used by curriculum planners), it is linear. However, it is different in that it has an inductive (grass-roots) approach rather than a deductive approach. The grassroots approach means that the teacher starts the curriculum development process by starting with specifics (identifying the needs of the students) and building to a general design (organizing and sequencing learning experiences). According to Taba, there should be "a systematic approach to initiating curriculum change". The proposed order of curriculum planning is as follows:

"Step 1: Diagnosis of Needs
Step 2: Formulation of Objectives
Step 3: Selection of Content
Step 4: Organization of Content
Step 5: Selection of Learning Experiences
Step 6: Organization of Learning Experiences
Step 7: Determination of what to evaluate and of ways and means of doing it. (pp. 11-12)"

Taba's model is linear. It proposes a certain order or sequence of progression through various steps.

Goodlad's Model

Goodlad elaborates the Tyler Rationale by bringing the concept of levels of curriculum decision-making to the discussion of curriculum development. These levels are instructional, institutional, and societal. The instructional level involves selecting "organizing centers for learning" (Goodlad & Richter, Jr., 1977, p. 510) and deriving educational objectives from the institution's educational aims. The institutional level involves formulating general educational objectives and selecting illustrative learning opportunities. The societal level is responsible for formulating educational aims in order to attain a set of selected values.

Johnson's Model

Johnson's model (1977) is called a production model because the central feature of this model is the distinction between process and product. FIGURE 2.3 is a portrayal of Johnson's model. Each process (the ovals in FIGURE 2.3) results in a corresponding product (the rectangles in FIGURE 2.3). For example, goal setting results in goals, curriculum development results in a curriculum, or instructional planning results in instructional plans. When applied to curriculum and instruction, this model consists of in five elements (1) goal setting, (2) curriculum selection, (3) curriculum structuring, (4) instructional planning, and (5) technical evaluation. These activities involve "frame factors" (natural, temporal, physical, economic, cultural, organizational and personal) which provide resources and restrictions on curriculum and instruction. One significant aspect of this model is that it makes explicit the importance of "frame factors" or context .

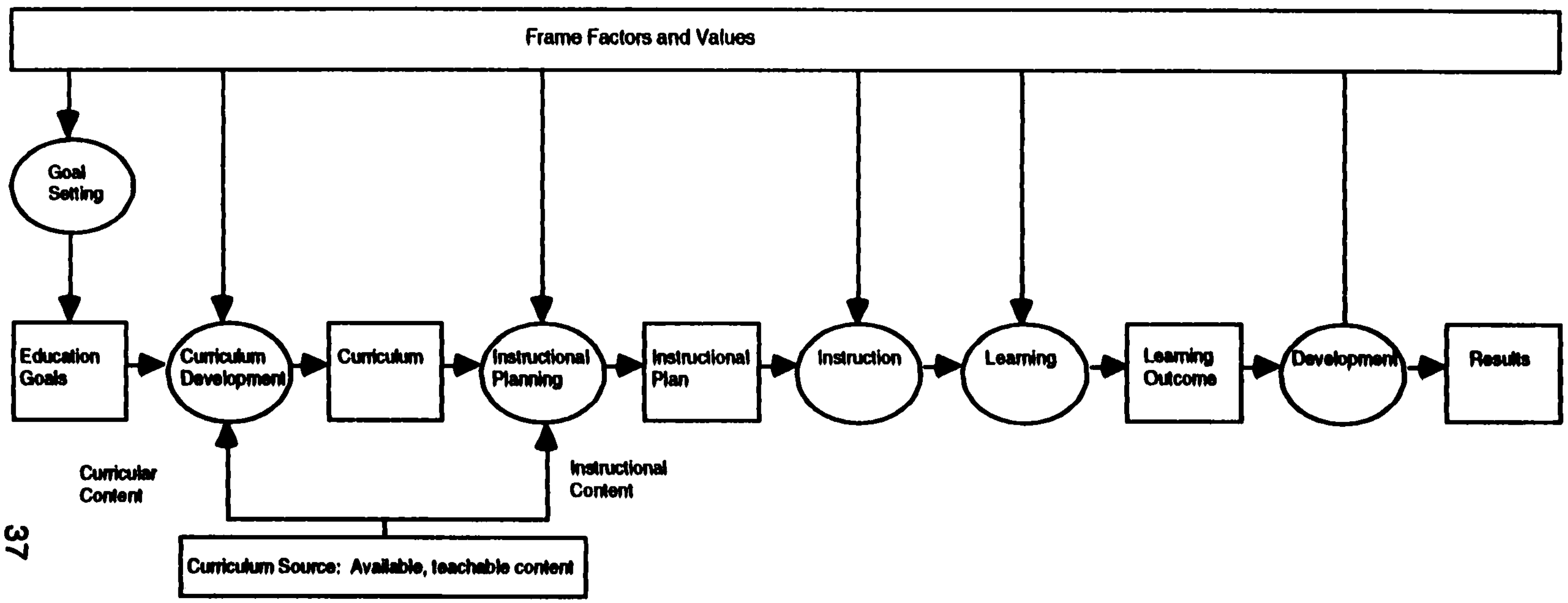

FIGURE 2.3 The Johnson Model

Schwab - Deliberation and the Eclectic

In addition to the four commonplaces described earlier in this chapter, Schwab brings the concept of deliberation to curriculum planning. Schwab (1970) describes deliberative inquiry as a methodology that seeks the unity of theoretical and practical ideas by bringing the agents of these ideas together in a specific problem solving context. He states that:

> "Deliberation is complex and arduous. It treats both ends and means and must treat them as mutually determining one another. It must try to identify , with respect to both, what facts may be relevant. It must try to ascertain the relevant facts in the concrete case. It must try to identify the desiderata in the case. It must generate alternative solutions. It must make every effort to trace the branching pathways of consequences which may flow from each alternative and affect desiderata. It must then weigh alternatives and their costs and consequences against one another, and choose, not the right alternative, for there is no such thing, but the best one (p. 36)."

Schwab also offers the "eclectic" as an approach to curriculum planning. The "eclectic arts" allows a curriculum planner to use various theories in combination" without paying the full price of their incompleteness and partiality (p.12)." Schwab recognized the complexity of the deliberative process and its political importance in securing the success of the curriculum as follows:

> "It will require the formation of a new public and new means of communication among its constituent members. Deliberation requires consideration of the widest possible variety of alternatives if it is to be most effective. Each alternative must be viewed in the widest variety of lights. Ramifying consequences must be traced to all parts of the curriculum. The desirability of each alternative must be felt out, "rehearsed, " by a representative variety of all those who must live with the consequences of the chosen action (p. 36)."

In the case of the Alberta senior high science program change, the stakeholders in science education were brought together through the consultation and communication process described in more detail in Chapter 4. The consultation and communication process, I believe can be aptly described as deliberation. The entire curriculum development process may described as an "eclectic" approach to curriculum planning.

Walker's Naturalistic Model

Walker's naturalistic model is a descriptive model which consists of three main elements of curriculum planning: its platform, its design and the deliberation associated with it. The platform is "the system of beliefs and values that the curriculum developer brings to his task and ... guides the development of the curriculum (Walker, 1971, p. 52)". Walker's curriculum design is not viewed as materials rather the events made possible by the use of materials. The design is specified by the process of deliberation or "the series of decisions that produce it... [that is] by the choices that enter into its creation (p.53)." Data are additional sources of information which may be used to devise alternative choices during the process of deliberation. Policy is referred to by Walker as "the body of precedents evolved from the platform" (pp. 57-58) or those principles that evolved from the application of the platform design decisions (Posner, 1988). One significant feature which Walker's model brings to the discussion of curriculum development is that the platform should be made explicit.

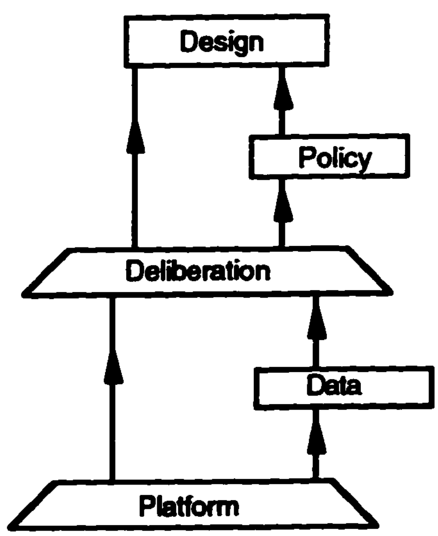

FIGURE 2.4 Walkers Naturalistic Model (Walker, 1971, p.58)

Aoki's (IDA/E) Model

Aoki's curriculum development model (IDA/E) is a holistic approach to curriculum development. Though the four questions of Tyler's model may be regarded as similar to the components that make up Aoki's model, Aoki's model is intended to be holistic rather than linear. The Aoki model has no beginning or end. The components of the IDA/E model are presented in FIGURE 2.5 Aoki's IDA/E Curriculum Development Model. The components are intents (I), displays (D), activities (A), and evaluation (E). Intents (I) are expressions of interests, desired goals or possibilities. They may be explicit written objectives or implicit desires or interests of individuals. Displays (D) are instructional or learning materials which are typically displayed, materials with which students and teachers interact in an instructional setting. Displays can be pictures, written materials, spoken words, maps, films, etc. Activities (A) refer to teacher and/or student activities defined together with "intents" and "displays". Class activities may be predefined by teachers or may occur in interactional situations. Evaluation (E) is an activity which occurs with the first step in program development.

Program evaluation and program development can be seen as two aspects of the same inquiry. These components are influenced by different perspectives. Perspective is a particular way of looking at life, a particular manner of construing the world. Understanding perspective provides us with an underlying rationale for our actions in that it provides us with a justification for acting the way we do. One way of making sense of instructional programs is to acknowledge the guiding principle of multiple perspectives. It allows us to entertain that underlying any program is a perspective, that developing intents, designing displays, teacher/student activities, or evaluating are perspective-guided activities, that the kind of interest, the form of knowledge, the mode of teaching, the way of learning, and the modality of evaluation which are embodied in a program reflect the underlying guiding perspective.

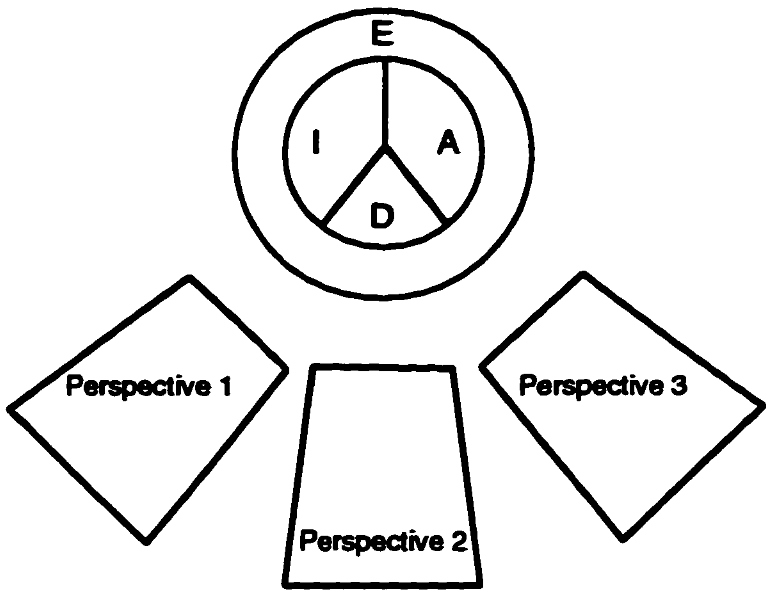

FIGURE 2.5 Aoki's IDA/E Curriculum Development Model

Aoki brings two significant aspects to the process of curriculum development. First, it is a holistic model. It acknowledges that the components cannot be separated. Second, it acknowledges the principle of multiple perspectives. The Alberta senior high science curriculum development process should be viewed as a holistic process occurring in a multicultural social and political context.

While each contributes to a way of viewing the curriculum development process, I suggest that these models do not adequately portray the complexity of a large-scale curriculum development project such as the development of the Alberta senior high science programs. In particular, the models do not depict issues related to curriculum organization, implementation or the complexities of the consultation and communication process.

Managing Curriculum Change

As new curriculum is developed to replace the previous curricula, another element of the curriculum development and implementation process that emerges is the management of change. What does the research say about managing curriculum change? Fullan (1989) argues that the 1970s were concerned with classroom practice and essentially with documenting failure of curriculum change or what not to do when implementing educational innovations. The 1980s were concerned with identifying and analyzing success and effectiveness in educational settings. Management of change for achieving successful outcomes is the next phase. This phase will concentrate on managing change and developing strategies for making it happen.

Fullan (1989) groups factors related to successful change into the three broad project phases of initiation, implementation, and institutionalization. He states that the initiation phase should meet four requirements: (1) the educational need should be linked to an agenda of political (high-profile) need, (2) a clear model should exist for the proposed change, (3) there needs to be a strong advocate for the change, and (4) there should be an early active initiation establishing commitment, as an elaborate planning stage is wasteful of energy. The implementation phase requires careful orchestration as implementation requires the clear direction of many players and a group is needed to oversee the implementation plan and carry it through. This phase also requires the correct combination of pressure and support, early rewards for implementers, and ongoing inservice training, to maintain commitment as behaviors often change before beliefs. The institutionalization phase of the change project will be more successful if it becomes embedded into the fabric of everyday practice, it is clearly linked to classroom practice, it is in widespread use across several classrooms and schools, it is not contending with conflicting priorities and it is subject to continuing inservice training for new staff, to consolidate commitment.

These factors came into play during the development of the Alberta senior high science program. The story of how Alberta Education managed curriculum change will become clear as the reader follows the story of the senior high science curriculum development project described in Chapter 4.

CHAPTER 3 THE CHANGING CONTEXT OF CURRICULUM DEVELOPMENT

Global Curriculum Development

Educational systems, globally, may be centralized, as in Mexico, Greece and France, or may be decentralized, as in the United States (Pinar, 1995). The curricula may vary from a general program outline (e.g., Ontario, Canada) to a detailed program of studies accompanied by centrally authorized student and teacher resources (e.g., Alberta, Canada). Development of these programs can involve extensive consultation, with teachers and other stakeholders in education, or very little consultation beyond the designated curriculum development individual or group. The operational curriculum often becomes influenced by standardized examinations which may be administered by a central government department, as in Alberta, or they may be administered by an external organization such as the standardized aptitude test (SAT) administered by the Educational Testing Service (ETS) in the United States.

Global reforms in science education are being directed or have been directed toward STS education (Aikenhead, 1994a). The purpose of STS education is to teach science in a meaningful way, through a social or technological context. It is claimed that this motivates students and prepares them to deal with science-based social problems outside the world of school (Solomon, 1994). Australia, Great Britain, the United States, Canada and other countries are or have been involved in STS curriculum development (Jenkins, 1990). Some of these STS curriculum projects include the PLON project (Dutch Physics Curriculum Project) in the Netherlands, *Science: A Way of Knowing* in Canada, *Science in Society*, the SISCON (Science in a Social Context)-in-Schools project and the Science and Technology in Society (SATIS) units in the United Kingdom, and Project Synthesis in the United States (Aikenhead & Solomon, 1994).

In 1972 in the Netherlands, the PLON project began to modernize and update the school physics curriculum by broadening its goals and later incorporating material on the interactions among physics, technology, and society. In 1973, Aikenhead and Fleming produced the first draft of *Science: A Way of Knowing*. In the United Kingdom in 1976, the Association for Science Education published *Science in Society*. In 1983, Solomon directed the SISCON (Science in a Social Context)-in-Schools project. In 1978, in the United States, the National Science Foundation funded Project Synthesis to derive recommendations for future action in science. Within this project, an STS focus group identified areas of concern and urged the inclusion of STS materials in science textbooks. In Victoria, Australia, in 1987, Malcolm, Cole, Hogendoorn, O'Keefe and Reid (1987) produced the *Science Framework* for the study of science from kindergarten through grade 10. The document very specifically promoted "science, technology, society and personal development" as the emphasis for science education. In 1992, the first Science and Technology in Society (SATIS) units were published by the Association for Science Education in the United Kingdom. Unlike the previous projects which were designed for the higher end of secondary education, the SATIS units were designed for the age range 8 to 14 years.

In Canada, provincial educational systems are moving or have moved in the direction of a science education program that achieves a more encompassing scientific literacy for all students than the "alphabet curricula" that were in place throughout North America during the 1960s and 1970s (Connelly, Crocker & Kass, 1985). The existing negative trends in enrollments, achievement and career choices are expected to be reversed by STS science education. Specifically, STS science is expected to increase general interest in and public understanding of science, particularly for the bright creative students who are discouraged by a boring and irrelevant curriculum (Bondi, 1985; Blades, 1992; Kahle, 1988; Science Council of Canada, 1984; Sjoberg & Imsen, 1988; Solomon, 1988).

The movement toward STS education in Alberta is illustrated by the objectives found in *Proposed Directions for Senior High Science and Graduation Requirements* (Alberta Education, 1987e) which include:

"• the retention of specific knowledge and understanding of the academic structure of science;

- an emphasis on an understanding of the nature of science, the development of process skills within the umbrella of critical thinking skills;
- an understanding of the relationship of science and technology;
- an understanding of the relationship of science and its social context;
- the development of life-long interests, intellectual curiosity, and appreciation of science;
- the applications of science, science related issues, and personal relevancy.

The global reforms toward STS education helped to provide direction for the development of an STS curriculum in Alberta.

Canadian Context and Curriculum Development in Canada

Section 93 of the Constitution of Canada states that education is the responsibility of the government of each province or territory. Each province or territory has a legal, administrative and financial responsibility for the development and provision of basic education. The department or ministry of education is headed by an elected member of the provincial legislature called the Minister of Education. A School or Education Act outlines the official policies and powers of each provincial government department of education. The responsibilities of the department of education generally include the supervision and inspection of schools; policies and guidelines for curriculum and school organization; approval of new courses and resources; finances, funding and capital expenditures; provision of special education programs; teacher certification and inservice education; regulations relating to the election and responsibilities of school trustees; delineation of the general responsibilities of board administrators, school principals and teachers; research and evaluation services; and support services such as libraries, audio-visual materials, textbooks and supplies, health, transportation, and counseling (Clarke, 1984). Local school boards, composed of elected trustees, control educational expenditures and the hiring of teaching staff. Local school boards, school principals and teachers share the responsibility for implementing programs in accordance with ministry or department of education documents (Connelly, Crocker, & Kass, 1985).

The curriculum development process varies from province to province. It involves complex consultative processes in which various public and professional groups (stakeholders) participate. Whether a province develops its own curricula or buys all or part of a curriculum already developed depends on several factors. One factor is the availability of usable curricula from other sources. During the 1960s, all jurisdictions bought, then selected from, the American science curricula: PSSC, HPP, CHEMStudy, BSCS (yellow, green and/or blue versions) and STEM. Another factor is the availability of resources such as money, time, energy and expertise. By the mid-1970s many provinces had responded to a call from the federal government for more Canadian content in all subject areas. Courses of study, textbooks, learning resources and teaching guides were produced. Some examples are *ALCHEM* in Alberta and *Intermediate Science and Environmental Science* in Ontario (Connelly, Crocker, & Kass, 1985).

Canada does not have a national office or federal ministry of education in Canada. However, the Canadian Ministers of Education Council (CMEC), established in 1967 and represented by the provincial ministers and deputy ministers of education, provides a forum for the various ministries to communicate, cooperate or coordinate formal positions or actions on major educational issues. It serves as a formal organization which can represent Canadian education at an international level. CMEC serves in an advisory capacity and may influence ministries of education or other organizations but it has no mandated authority.

Since education is a provincial matter and there is no federal ministry of education, it is uncommon to find national studies related to educational issues. Two notable exceptions, related to science education, are *Science Education in Canada* (Connelly, Crocker, & Kass, 1985) and *Report 36, Science for Every Student, - Educating Canadians for Tomorrow's World* (Science Council of Canada, 1984).

The *Science Education in Canada Study, Volume 1: Policies, Practices and Perceptions* discusses "intended and translated science curriculum, science teacher education practices, science teacher perceptions, and science student assessment procedures, in a historical and current Canadian context (Connelly, Crocker, & Kass, 1985, p 311)." This study provides a context for science curriculum development in Canada.

The Science Council of Canada (1984)*Report 36, Science for Every Student, - Educating Canadians for Tomorrow's World* is a summary of the research program which included newsletters, discussion papers, workshops, a three-volume background study entitled *Science Education in Canadian Schools*, (Science Council of Canada, 1983) and a deliberative phase which involved the circulation of an interim report to participants of eleven deliberative conferences and the advice and recommendations from the conference participants. The two main thrusts of the study were: "to investigate the past and present place of science education in Canadian schools and to develop recommendations for its future directions (Science Council of Canada, 1984, p. 9)."

Report 36 (Science Council of Canada, 1984), published after four years of study, provided considerable impetus for the revision of science curricula across Canada, particularly in Alberta. It stated that as the "rate of change increases and the world becomes ever more complex, Canadian students need more and better science education to prepare them for the future (p. 9)" and it concluded that "renewal of science education is essential (p. 9)." The report further stated that "for Canada to cope with social changes rooted in highly specialized technologies, its citizens need the best *general* education possible - an education comprising not only the traditional basics of language and mathematics, but also the *new* basics of our contemporary culture: science and technology (p. 9)."

The Council believed that the "goal of scientific literacy for all could be achieved through a balanced curriculum in which science is taught with four broad aims in mind:

- to encourage full participation in a technological society;
- to enable further study in science and technology;
- to facilitate entry into the world of work

- to promote intellectual and moral development of individuals (Science Council of Canada, 1984, p. 10)."

The "major findings" of the study identified a serious gap between what science education was *supposed* to achieve and what it *actually* achieved. For example:

- science is rarely taught adequately (if at all) in elementary schools across the country;
- students enthusiastic about science and those achieving above-average marks complain about the lack of challenge in their schools;
- very little is being taught about the crucial interaction among science-technology-society;
- many girls still do not see scientific or technological careers as being relevant to them, and turn away from science; both Canada and half of its citizens are the losers;
- teachers complain about the lack of ineffectiveness of inservice programs for their own development;
- there are a few openings for young people entering the teaching force, and older teachers have little incentive to innovate or strive for excellence (Science Council of Canada, 1984, p. 10)."

As a result of its analysis of the "state of science education in Canadian schools, the Council recommended eight major initiatives required for the renewal of science education. These initiatives are summarized as follows:

"Science Education for All

1. Guaranteeing science education in every elementary school
2. Increasing the participation of young women in science education
3. Challenging high achievers and science enthusiasts

Redirecting Science Education

4. Presenting a more authentic view of science
5. Emphasizing the science-technology-science connection
6. Setting science education in a Canadian context
7. Introducing technology education

Monitoring Science Education

8. Ensuring quality in science education (Science Council of Canada, 1984, p. 11)"

The Council also presented 47 specific recommendations designed to implement these initiatives. Several of these recommendations were addressed during the Alberta senior high science curriculum development process.

The results of the Science Council of Canada study became a focal point for the first round of curriculum revision of the Alberta science programs (to be discussed in Chapter 4) because the study provided a basis from which to examine existing science programs and it established a backdrop against which recommendations for future change could be developed. What evidence supports the impact this report had on the development of the new science programs? *Report 36* (Science Council of Canada, 1984) was provided to every member of the Alberta Education Science Team. Statements from the report were frequently quoted in documents (Alberta Education, 1986c; Alberta Education, 1987b), and in presentations made by Alberta Education representatives (Alberta Education, 1990h). "More and better science" became a catch phrase used by many members of the department of education, including the Minister of Education (Alberta Education, 1990a). The goals of scientific literacy were developed in the program rationale and philosophy. The program rationale and philosophy is found in the first section of each of the senior high science programs of study. An example from the Science 10 Course of Study is presented in Appendix D. The major findings were addressed through the inclusion of STS in the programs of study and through the extensive inservice activities provided by Alberta Education and there was an attempt to address the 47 recommended initiatives through various strategies for implementation provided in the report. For example, Strategy for Implementation # 5 states that

> "Ministries should incorporate a science-technology-society emphasis in science courses at all levels... This policy should also influence textbook selection (Science Council of Canada, 1984, p.48)"

In response to this strategy for implementation, Alberta Education has since revised the science programs at the elementary, junior high and senior high levels and, when a suitable general science textbook with an STS emphasis could not be found for the Science 10-20-30 program, the textbooks for these courses were custom published.

During Round 2 of the curriculum revision (to be discussed in Chapter 4), the report *Science for All Americans* (AAAS, 1989) had considerable influence (Lantz, 1991, p. x). The report consists of a set of recommendations by the National Council on Science and Technology Education - a group of scientists and educators appointed by the American Association for the Advancement of Science - on "what understandings and habits of mind are essential for all citizens in a scientifically literate society (p. 3)". The report stated that "scientific literacy has emerged as a central goal of education and it defined a scientifically literate person as

> "one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes (AAAS, 1989, p.3)."

As was stated earlier, scientific literacy was a major goal of the Alberta senior high science programs so the appearance of the AAAS document served to validate, in an external sense, this aspect of the Alberta senior high science program reform.

Science for All Americans (AAAS, 1989) contains chapters which (1) focus on the nature of science, mathematics, and technology as human enterprises, and on how they resemble and differ from one another, (2) present basic knowledge about the world (3) set forth what people should know about great episodes in the history of the scientific endeavor and about key crosscutting themes and (4) focus on the habits of mind that are essential for scientific literacy. As with the goal of scientific literacy, many of the recommendations contained in these chapters were incorporated in the development of the new Alberta senior high science program and again the program directions were perceived as being validated. A comparison of the following excerpt from the AAAS report summary with the *Science 10 Program Vision, Rationale and Philosophy, and General Learner Expectations* (Appendix D) reveals the similarity.

> "Certain next steps are essential if the nation is going to make significant headway toward realizing the goals expressed in *Science for All Americans.* Those steps should reflect the following considerations:
>
> - To ensure the scientific literacy of all students, curricula must be changed to reduce the sheer amount of material covered; to weaken or eliminate rigid subject-matter boundaries; to pay more attention to the connections among science, mathematics, and technology; to present the scientific endeavor as a social enterprise that strongly influences - and is influenced by - human thought and action; and to foster scientific ways of thinking.
> - The effective teaching of science, mathematics, and technology (or any other body of knowledge and skills) must be based on learning principles that derive from systematic research and from well-tested craft experience. Moreover, teaching related to scientific literacy needs to be consistent with the spirit and character of scientific inquiry and with scientific values. This suggests such approaches as starting with questions about phenomena rather than with answers to be learned; engaging students actively in the use of hypotheses, the collection and use of evidence, and the design of investigations and processes; and placing a premium on students' curiosity and creativity (AAAS, 1989, p. 5).

In summary, the documents *Science Education in Canada* (Connelly, Crocker, & Kass, 1985), *Report 36, Science for Every Student, - Educating Canadians for Tomorrow's World* (Science Council of Canada, 1984) and *Science for All Americans* (AAAS, 1989) provided significant direction for the revision of the current Alberta senior high science programs.

CHAPTER 4 THE ALBERTA APPROACH: A CASE STUDY OF THE PROCESS OF LARGE-SCALE CURRICULUM DEVELOPMENT

This chapter presents a description of the characteristics of the Alberta senior high science curriculum development process, the components of the curriculum development process and the interrelationships of these components. The first section describes the organizational structures of Alberta Education curriculum development projects. This will provide a sense of the characteristics of the curriculum development process. In the second section, I will examine the curriculum development components, their interrelationships and the patterns of consultation and communication within the context of my overall thesis question.

The Role of Alberta Education in Curriculum Reform

Alberta Education consists of several different departments or branches, each having their own roles and responsibilities and input into or influence on different aspects of the development of the new science programs. Alberta Education has undergone major reorganization twice (1988 and 1994) since the beginning of the development of the Alberta senior high science programs. The organizational structure of Alberta Education depicted in FIGURE 4.1 and described below is based on the organizational structure of Alberta Education as of 1990-91, the beginning of the period delimited by my study. An overview of each branch is included to clarify the relationship each branch has to the development of the new senior high science programs. The various units are described as they are presented in the Annual Report (Alberta Education, 1990d).

The **Human Resource Services** division manages personnel programs and services, assisting and providing information regarding staff recruitment, transfer and promotion and termination; job classification; employee relations; and performance management. The branch also provides a variety of training programs.

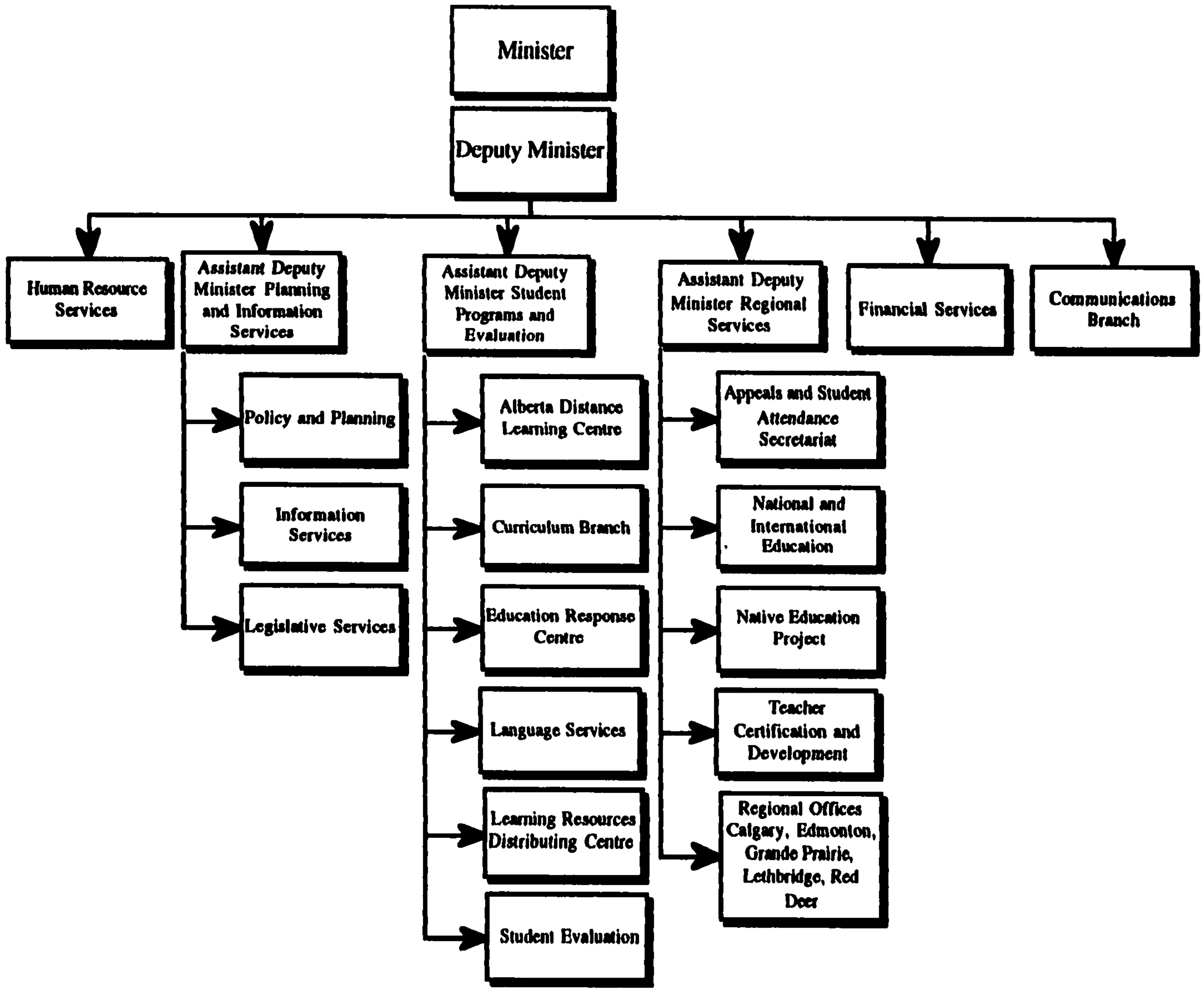

FIGURE 4.1 Alberta Education Organization Chart 1990-91

The **Planning and Information Services** division plans and initiates new projects and assists Alberta Education and school jurisdictions in planning activities that improve the quality of education. This division also collects data and other information, and provides analyses and reports to the department and to school boards. Finally, the division reviews legal issues in education and seeks opinions from the Attorney General in these areas. Planning and Information Services consists of three branches (1) Policy and Planning, (2) Information Services and (3) Legislative Services. The Policy and Planning branch coordinates government educational policy, developed the Educational Quality Indicators (EQI), and conducts surveys of business, industry and the public. The Information Services Branch coordinates the Educational Information Exchange (EIE), a province-wide student registry and electronic student data exchange for use by Alberta Education and school boards. Legislative Services deals with legal issues including amendments of the School Act, the Department of Education Act, copyright law, legal advice to appeal bodies administered by Alberta Education, and the legal aspects of establishing and dissolving school districts. Policy and planning provided the guidelines of educational policy for the development of the new science programs. Information services provided information about school jurisdictions, schools and teachers for mailouts, and Legislative services was consulted for legal advice regarding the development of the custom developed textbooks for Science 10-20-30.

The **Student Programs and Evaluation** division creates, reviews and revises provincial school programs and learning materials for teachers and students. The division also creates, administers, marks and reports results on provincial achievement tests and diploma examinations. The divisions consists of six branches (1) Alberta Distance Learning Centre, (2) Curriculum Branch, (3) Education Response Centre, (4) Language Services, (5) the Learning Resources Distribution Centre and (6) Student Evaluation Branch.

The Alberta Distance Learning Centre develops distance learning packages and independent learning programs primarily for senior high courses. These packages include print materials, question banks, audio and video tapes, and Computer Assisted Instruction projects. Curriculum branch is responsible for creating, reviewing and revising programs and learning materials. The branch is currently called the Curriculum Standards Branch. The Education Response Centre (ERC) worked with issues relating to special education such as, integration of special need children into the regular classroom and improving coordination of services to special needs children. The ERC is now called the Special Education Branch and is part of Regional Services. The Language Services branch is responsible for creating, reviewing and revising programs and learning materials in languages other than English (e.g., French, German, Ukrainian, Japanese). Translation of the programs of study and resources is done by Language Services. The Learning Resources Distributing Centre provides learning resources, including basic and support resources for the science programs, for Alberta's teachers and students. Student Evaluation Branch is responsible for the creation, administration, marking and reporting of results on provincial achievement tests and diploma examinations including diploma examinations for Science 30, Biology 30, Chemistry 30 and Physics 30. The branch has also been involved with the School Achievement Indicators Program (SAIP) under the direction of the Council of Ministers of Education (CMEC).

The **Regional Services** Division works closely with school jurisdictions and communities throughout Alberta and provides them with consulting, administrative, evaluation and planning services. This division also provides direct services to students and teachers, including exchange programs and teacher certification services. In 1993-94, Regional Services was restructured. This included the closure of the Regional Offices in Red Deer and Grande Prairie. This division consists of five branches: the Appeals and Student Attendance Secretariat, National and International Education, the Native Education Project, the Teacher Certification and Development Branch, and the Regional Offices of Education. The Appeals and Student Attendance Secretariat is responsible for student appeals and tracking student attendance. National and International Education coordinates student (language) exchanges, teacher exchanges, joint ventures with other countries, and international school partnerships. The Native Education Project is involved with implementing the provincial Native education policy, monitoring and evaluating progress of school jurisdictions offering Native education programs and assisting the development of a curriculum for Cree 10-20-30 and Blackfoot 10-20-30. The Teacher Certification and Development Branch revises regulations related to teacher certification and provides support for the Council on Alberta Teaching Standards (COATS). COATS makes recommendations on teacher preparation, teacher supply and demand, and teacher professional development. They also resolve complaints of unskilled teaching practice and sponsor an Excellence in Teaching Awards program. The Regional Offices of Education support, advise and communicate with school boards, private schools, and Indian band-operated schools in their regions. They help schools implement programs by providing inservice, professional development, workshops and awareness sessions. They coordinate reviews of disputes and respond to appeals on student suspensions and expulsions. They coordinate school system reviews, prepare evaluation reports, monitor results achieved in selected subject areas and monitor the progress of schools and school boards in developing policies. The Regional Office science consultants were consulted during the development and implementation of the new senior high science programs.

The **Financial Services** Division provides financial and administrative services to support Alberta Education's programs, priorities and initiatives including the development and implementation of the new senior high science programs. The division distributes grants to school boards and administers funds for Alberta Education's internal operations. The division also provides financial and administrative advice and support to school boards and to Alberta Education staff. They distribute provincial grants for instruction, student transportation and school capital, for example, capital funding to build, modernize or upgrade schools.

The **Communications** branch works with all branches of the department to keep Albertans informed about programs, initiatives, services, and policies. The branch also publishes *in•fo•cus*, a provincial newsletter and *Intercom*, the department's internal newsletter.

Stakeholders in Science Education

There are a variety of stakeholders in science education including teachers, Alberta Education staff, school jurisdiction consultants and administrators, post-secondary instructors in education and science, representatives from science and technology-based business and industry, other science and technology related departments in the government such as Alberta Agriculture, Alberta Environment, Alberta Energy, Alberta Forestry, Lands and Wildlife and professional organizations such as Council of Alberta School Superintendents, the Alberta Teachers Association (ATA), ATA subject councils such as the ATA Science Council, Alberta Home and School Councils' Association, Alberta School Board Association, Association of Professional Engineers Geologists and Geophysicists of Alberta, the Alberta Medical Association, Alberta Chamber of Resources, Alberta Chamber of Commerce, University Co-ordinating Council and the Council of Presidents of Public Colleges and Technical Institutes of Alberta that were consulted during various stages of the curriculum development project.

The role of Alberta Education and the stakeholders in science education related to the development and implementation of the Alberta senior high science program will be discussed further as the story unfolds. We turn now to a consideration of the thesis questions.

Thesis Question 1

What are the characteristics of curriculum development in a complex, multidimensional, dynamic environment?

Two major frameworks used to guide curriculum development in Alberta will be discussed in this section: the Program Development Cycle, which outlines the stages of development, and Designing a Program for Students, which includes considerations that go into the development of a program.

Program Development Cycle

The Alberta Education document *Who Decides What Students Should Learn in School ... and How?* was published to explain to stakeholders in education how curriculum revision or curriculum development occurs in Alberta. FIGURE 4.2 presents the Program Development Cycle which represents key stages of this process. The development and implementation model is more complex than it is presented in this model however like many models it serves to provide a framework for discussion. I will present a description of how the model is supposed to work then proceed to describe the events associated with the Alberta senior high science curriculum development process as documented in the timeline in Appendix C and recollected by members of the Science Team.

Palmer (1989) states that several reasons may be cited for revising or developing a new program. These include replacing an outdated program, new knowledge about student learning and development, changing needs of students and society, new knowledge in a subject, need for continuity and consistency among programs or major policy changes within the government. Any or all of these reasons could prompt a preliminary evaluation of a program. Most of these were cited as reasons for revising the Alberta senior high science program.

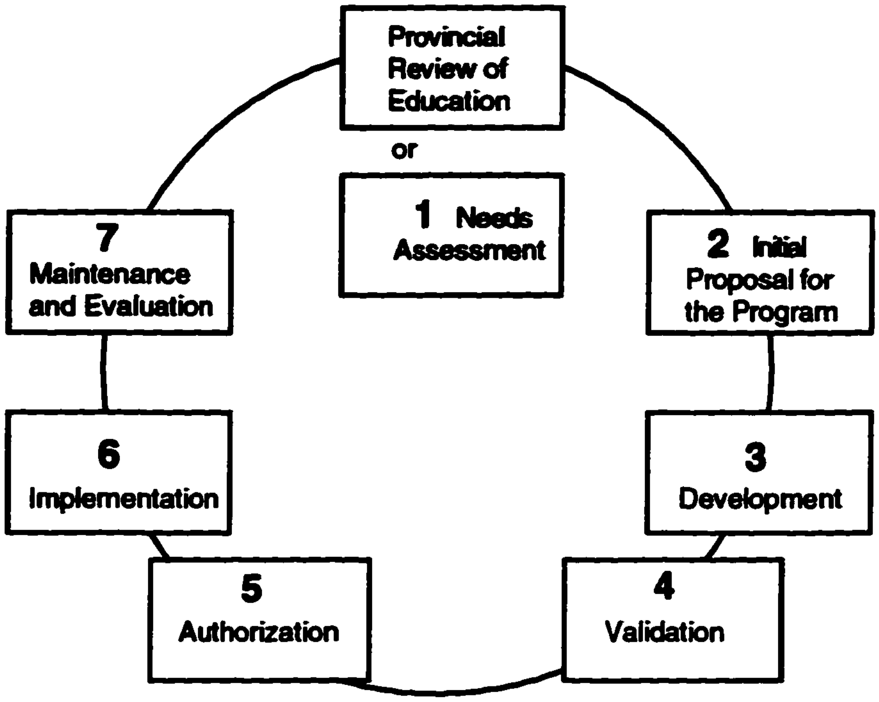

FIGURE 4.2 The Program Development Cycle

Traditionally, curriculum changes in Alberta begin with a **needs assessment** or **provincial review of education**. Alberta Education would perform a preliminary evaluation involving the submission of a Memorandum of Intent to the Senior High Program Coordinating Committee which was an external committee comprised of stakeholders in education. The Memorandum of Intent would include a list of concerns, possible changes, implications of the changes and a statement of what prompted the preliminary evaluation. The committee would make recommendations outlining the parameters of a formal needs assessment which would be approved by the Assistant Deputy Minister of Education. Upon approval, a formal Needs Assessment Proposal would be prepared by the assistant director responsible for the subject area. The proposal would include a background rationale, the methods for gathering the data, the timelines, the stakeholders to be consulted, the inter branch roles and responsibilities, the budget and communications plan. The proposal would be approved by the Senior High Program Coordinating Committee and the Minister before the Needs Assessment would be conducted. The Needs Assessment would provide an opportunity for stakeholders to have input and would provide data for analysis by Alberta Education.

Following analysis of the data collected in the Needs Assessment, an **Initial Proposal for Program Change** would be drafted. This proposal would include a summary of the proposed changes, background of the method and results of the needs assessment, the recommended changes, a rationale for the changes, the proposed development process, a cross-curriculum impact description, the anticipated consequences for Alberta Education Branches and schools, and a brief summary of input from the Senior High Program Coordinating Committee, Management Council and Division Council. Management Council is composed of the director and assistant directors within a branch. Division Council is comprised of the assistant deputy minister and the directors within a division. The Minister of Education makes decisions regarding program development requirements related to the programs of study, changes to student resources or changes to teacher support.

The **Development Stage** can be further subdivided into Project Management, the Project Plan, Program Development and Internal Validation. Project Management begins with the appointment of a project manager, often a seconded teacher, to work with a program advisory committee and one or more sub-committees of educators who would be responsible for the development of the new program. The program manager would be selected on the basis of having the necessary expertise to develop credibility in the subject area, current expertise and preparation in curriculum development and planning and project management expertise including communications skills and a teamwork orientation. The program manager would establish an advisory committee so as to ensure input from generalists as well as specialists and balance of representatives from across the province as outlined in the Initial Proposal. The committee structure would be approved by the Director of Curriculum Branch. The Project Plan would be developed by the program manager and the inter branch team. The inter branch team would include corresponding subject area staff from other branches such as exam managers from Student Evaluation Branch and the program managers from Alberta Distance Learning Centre. The Project Plan would include the main features of the new program, how the program would be validated, the implications with respect to the implementation of the program and the associated costs related to learning resources, teacher support resources, programs in French or other languages, implications regarding student achievement tests, school facilities and resources, implications of and for the uses of technology and teacher inservice, a communication plan, how the program will be evaluated, the timelines, roles and responsibilities of Alberta Education staff, budget and a statement of any variation from the Initial Proposal. The project plan would be approved by the Director. Program Development involves the production of the draft program of studies, teacher support publications (if required by the proposal) and the identification of potential basic resources. The program of studies must be consistent with contemporary learning and teaching research, be consistent with current Alberta Education policies, address larger societal concerns, contain a program rationale and philosophy, general and specific learner expectations, and take into account the full range of student differences, needs and abilities. The draft materials are reviewed by a broad base of educators using methods such as regional meetings. Internal Validation means that the program of studies and basic learning resources are validated with respect to essential learnings, developmental appropriateness, instructional design, and tolerance and understanding.

The **Validation** stage would involve field validation and final revisions. Field validation is done to assure that the program of studies and basic resources "work" in the classroom. The original field validation proposal contained within the project plan should be reviewed and adjusted. The proposal should include the number of classes required, the duration of the field validation, a calendar or schedule for proposed activities, the distribution of field validation classes with respect to such factors as urban/rural, large school/small school, public/separate, the extent of inservice activities with field validation teachers to provide full feedback in field validation, the nature and frequency of contact during the field validation period, how to provide ongoing consultation with field validation teachers, evaluation procedures as they relate to the field validation program and financial implications of the field validation program such as staffing, equipment, materials and facilities. Field validation teachers should represent a variety of conditions (e.g., specialist/generalist, urban/rural, school level/jurisdiction level) and the selection of the field validation classes should be done in consultation with school system personnel with information regarding the implications of the field validation conveyed to all concerned. Revisions to the program of studies occur during, and subsequent to, the field validation. The details and outcomes of this strategy are documented in Romanyshyn (1996).

Authorization of the program of studies means that the Minister has given final approval. The Minister is given the appropriate documents, program of studies, a memorandum that Alberta Education program policies have been addressed, a summary of the field validation and a summary of reviews by the Senior High Program Coordinating Committee and Division Council. Support documents, support resources and teacher resource manuals are approved by the Assistant Deputy Minister.

Implementation involves document production and distribution and the orientation of teachers. Document production and distribution involves ongoing communication to the field, a communications plan for public and parents and when documents are distributed they must include information on student and teacher resources, implementation dates, changes in the new program, orientation plans, and availability of additional curriculum documents. The implementation plan should be reviewed and adjusted so that teachers are familiar with the new program and are comfortable about beginning implementation.

Maintenance and Evaluation involves ongoing support to teachers in their implementation of the programs, assessment of student growth and ongoing feedback regarding the effectiveness of the program.

Although all aspects of the Program Development Cycle occurred in the development of the senior high science programs as will be discussed later in this chapter, the process was not sequential as portrayed in the Program Development Cycle.

Designing a Program for Students

When Alberta Education revises or designs a new program (the Development Stage described above) there are a multitude of considerations that guide their decisions and actions. FIGURE 4.3 Designing a Program for Students presents an outline of the components that go into the making of a program. The sections which follow describe the various components. While FIGURE 4.3 implies a progression of activities there is no hierarchy of importance that is implied beyond what is suggested by a logical progression. The various components interact and intersect at multiple levels. Each major category will now be described in turn.

In Alberta, the general **goals of education** are viewed as a shared responsibility of the community. Specific goals of schooling, basic to the broader goals of education, are the responsibility of schools. School programs and activities are planned, taught and evaluated on the basis of these specific goals. The goals of education and goals of schooling apply to all subjects and all grade levels. The secondary education policy outlines the aims and goals specific to secondary education. These aims and goals provide a foundation for the development of all secondary programs in Alberta. These are described in detail in the *Guide to Education* (Alberta Education, 1993).

In keeping with the secondary education policy, Alberta Education prepared support materials to guide the development of new programs for students. For example, in May 1987, Alberta Education completed a catalogue entitled, ***Essential Concepts, Skills and Attitudes for Grade 12*** (Alberta Education, 1987d). The catalogue listed the most important things for students to learn in junior and senior high school programs. The essential concepts, skills and attitudes are organized into ten groups: self-concept and lifestyle, interpersonal relations, critical and creative thinking, communication, science and mathematics, lifelong learning, citizenship, career exploration, consumer product awareness and global and environmental awareness. Each group is organized into several statements under the headings of concepts, skills and attitudes. Though the catalogue was not official "policy" it was used by

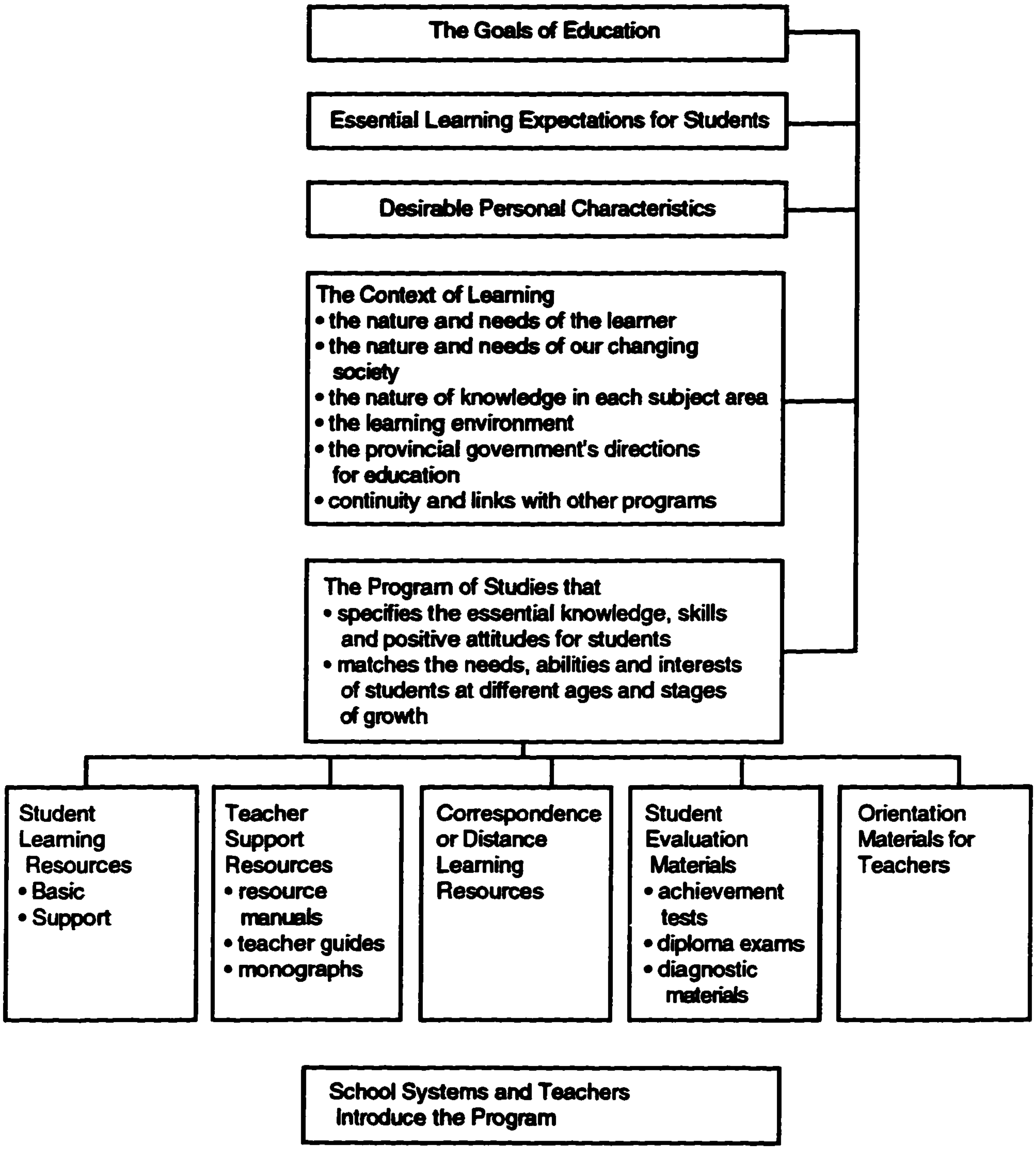

FIGURE 4.3 Designing a Program for Students (Palmer, 1989, p.8)

curriculum developers to guide the design, implementation and evaluation of several courses and programs for senior high school.

In addition to developing essential concepts, skills and attitudes, schools play a role in developing **desirable** ethical/moral, intellectual, and social **personal characteristics** among school age children. These characteristics also provided a foundation upon which to build a new program. These are also described in detail in the *Guide to Education* (Alberta Education, 1993).

Palmer (1989) expands the **contexts for learning**. The Nature and Needs of the Learner refers to the intellectual, social, emotional and physical needs and abilities of students at different ages and stages of growth, the ways students learn best, the special needs of students (learning disabilities and gifted or talented) and the continuity in what students are expected to learn from subject to subject and grade to grade. The Nature and Needs of Our Changing Society refers to the social, cultural, economic, technological and political changes taking place in Alberta, Canada, and other areas of the world and to the provincial, national and global issues of today and tomorrow. The Nature of Knowledge in a Subject Area refers to the major discoveries or new theories in each field of study and the extent to which these are accepted among the experts, the thinking skills that are the foundation of each field of study, the links between one subject and another and the relevance of the subject to students' learning and development. The Learning Environment refers to the major features of the learning environment (the school, the community, the home), the needs of teachers who guide the learning of students, the facilities, equipment and all of the support materials required to offer the program successfully, and the ways in which the program can best be delivered to students - the use of new technologies, and the learning experiences that can be provided by community members and agencies. The Provincial Government's Directions For Education refers to the School Act, the Goals of Basic Education, the Secondary Education Policy, the Language Education Policy, the Native Education Policy, the Controversial Issues Policy and the Policy of Metrication. Continuity and links with other programs are reviewed by the Senior High Program Coordinating Committee.

As stated earlier in the description of the Development Stage of the Program Development Cycle, the **program of studies** must be consistent with contemporary learning and teaching research, be consistent with current Alberta Education policies, and address larger societal concerns. The program of studies must contain a program rationale and philosophy, general and specific learner expectations.

Student Learning Resources refer to basic and support resources. Palmer (1989) states that Basic learning resources, such as textbooks, audiovisual materials, and computer software, address eighty percent or more of the major learning expectations in the programs of study. Basic resources must meet criteria related to tolerance and understanding, instructional design, considerate text, and appropriateness to child development. These criteria are outlined by the Learning Resources Unit within Curriculum Branch. Basic resources are available from the Learning Resources Distribution Center (LRDC). Traditionally in Alberta, the basic learning resource has been a textbook. Support learning resources for students address some of the ideas in the program of studies, and help students develop their particular interests and talents. Support resources also meet tolerance and understanding criteria. Many are available from the LRDC, through the ACCESS network or Regional Resource Centres and Urban Media Centres.

Support resources for teachers include materials that help teachers prepare lessons and select teaching methods that are suited to the individual needs of their students; for example, teacher resource manuals, teacher guides to basic textbooks, and monographs.

Distance learning resources include materials that enable students to take a course they might not fit into their timetables, to take a course not offered by their local school or to help students work through a course at their own pace.

Student Evaluation materials include provincial achievement tests and diploma examinations. These materials are designed to help determine how well students have achieved the learning expectations in the science programs of study, if any changes should be made to the programs or the way they are being offered to students and diagnostic materials that teachers use to assess and help each student strengthen skills in reading, writing, speaking and mathematics (Palmer, 1989).

Orientation materials for teachers are materials that introduce teachers to a new or revised program of studies and help them decide how to present the program to the students.

The Program Development Cycle and Designing a Program for Students provide a framework for the curriculum development and implementation process in Alberta. With this background, my story of the development and implementation of the current Alberta senior high science program is ready to unfold.

The Need for Senior High Science Curriculum Reform in Alberta

The revision of the current senior high science program began with a provincial review of education called the *Review of Secondary Programs* (Alberta Education, 1985a). This review provided the recommendations for revisions of the Secondary Education Policy. The policy change was followed by development of documents on student developmental growth and essential concepts, skills and attitudes, an *Instructional Program Review* (Alberta Education, 1986a), the *Secondary Education Action Plan*, (Alberta Education, 1986b) and ultimately the *Proposed Directions for Senior High School Programs and Graduation Requirements* (Alberta Education, 1987e). FIGURE 4.4 The Need for Change provides a summary of the events that occurred preceding the development of the current senior high science program. This corresponds with the first two stages of the Program Development Cycle described earlier. A comprehensive timeline of the development process is presented in Appendix C.

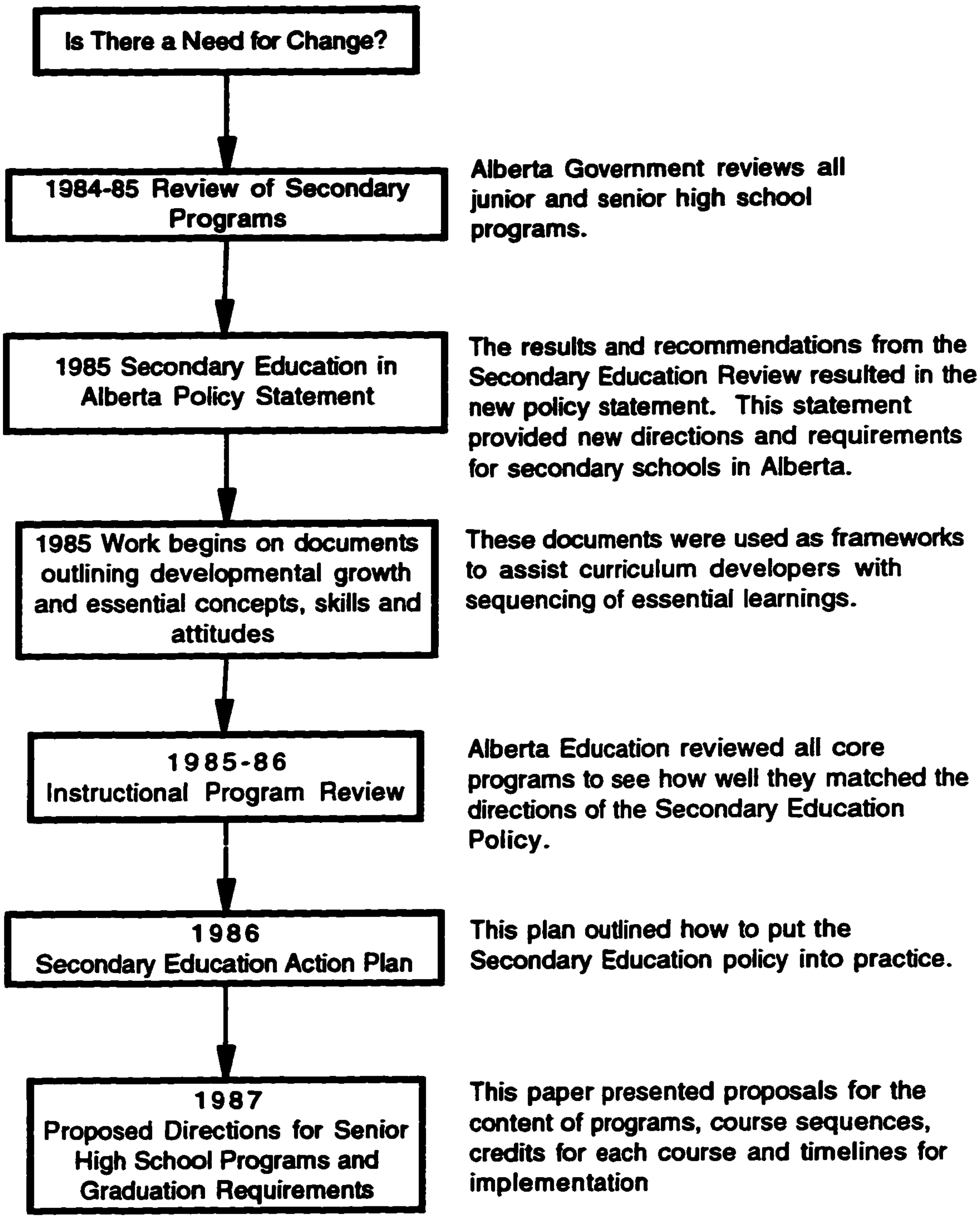

FIGURE 4.4 - The Need for Secondary Science Curriculum Reform

The Review of Secondary Programs (1984-85)

In 1984, the Alberta Government began a comprehensive review of all junior and senior high school programs to determine the nature of curriculum reform most appropriate to prepare students for life in a rapidly changing society. As part of the review process, an advisory committee, chaired by a member of the legislative assembly, gathered suggestions and advice. A Gallop poll and over 100 briefs were received from groups within and outside the education community. Questionnaires were distributed to households across Alberta and approximately 10,000 responses were received, recorded and analyzed (Alberta Education, 1985b). Many Albertans and groups of Albertans wrote letters and phoned Alberta Education presenting their views. Suggestions were also received from over 3000 students through meetings and surveys and a special advisory committee provided additional advice to the Minister of Education. The committee reviewed past changes and events taking place in other provinces and countries. Information about young people in high schools and reasonable forecasts of Alberta's and Canada's future were also analyzed. The committee presented its findings and recommendations in three booklets entitled, *Review of Secondary Programs: Alberta's Secondary Education Programs: The Public's View, Alberta's Secondary Education Review: Research Basis* and *Report of the Minister's Advisory Committee: Foundation for the Future* (Alberta Education, 1985a). Taken together, the committee's activities and recommendations resulted in the new secondary education policy.

The Secondary Education in Alberta Policy Statement (June 1985)

In 1985, results and recommendations coming out of the *Review of Secondary Programs* (Alberta Education, 1985a) were published in the policy report *Secondary Education in Alberta (Alberta Education, 1985b).* The policy set new directions and requirements for secondary schools and called for changes that had been suggested by many Albertans. The policy's framework for secondary school programs included the following requirements in the area of science and made numerous recommendations about areas of the secondary school curriculum:

- science will continue to be a core (mandatory) program for all junior and senior high school students
- the junior high science program will be a general one, emphasizing problem solving, basic scientific concepts and principles related to the student's experience, the role of science in society, with consideration given to technology, the application of science, the societal, technological, and environmental impact of science, and the moral and ethical issues that accompany the use of scientific knowledge.
- senior high school students who wish to obtain a General High School Diploma will complete a minimum of two science courses (as of September, 1989)
- senior high school students who wish to obtain an Advanced High School Diploma will complete at least one of the following Grade 12 science courses: Biology 30, Chemistry 30, Physics 30 or Science 30 (as of September 1991)
- the senior high school science program will include an understanding of basic scientific concepts and their application to our world
- there will be an academic science program (Science 20-30) as an alternative to the specialized study of biology, chemistry, or physics, and this science program will be a three course sequence
- students are to complete courses in Grades 10, 11, and 12 with a minimum mark of 50% in order to obtain a high school diploma. (Alberta Education, 1985b, p.21-24)

The recommendations for science were similar to those of the Science Council of Canada as expressed in its report, *Science for Every Student: Educating Canadians for Tomorrow's World* (Science Council of Canada, 1984) (see also p. 48); and those presented by the Alberta government in a White Paper entitled *Proposals for an Industrial and Science Strategy for Albertans 1985-1990* (Government of Alberta, 1984). This White Paper indicated that "education should foster ideas of risk-taking, innovation and pursuit of excellence" (p. *x*). It cited the need to prepare youth to grapple with the difficult problems facing society and to shape the future through their actions.

Developmental Growth Monographs (August 1985)

A major thrust of the secondary education policy statement was to ensure that courses that are developed take account of changes in students' growth. The knowledge, skills and attitudes that students are capable of learning change as students grow and mature. Hence, the ways in which they learn may also change as students grow and mature.

In August 1985, work was started on developing a framework to assist curriculum developers and classroom teachers by depicting students' growth in cognitive, affective and physical domains. A series of monographs entitled: *Students' Thinking: Cognitive Domain* (Alberta Education, 1987f), *Students' Interactions: Social Sphere* (Alberta Education, 1987g), *Students' Physical Growth: Physical Dimension* (Alberta Education, 1987h), and *The Emerging Student: Relationships Among the Cognitive and Social and Physical Domains* (Alberta Education, 1991d) were published in 1987 and 1991. These monographs were used as resource documents by the various curriculum development teams in designing the programs.

Essential Concepts, Skills and Attitudes (September 1985)

At a more specific level work began in September 1985 to identify the concepts, skills and attitudes which were considered essential and are expected of all high school graduates in order for them to function effectively in society. These essential learnings were not subject specific but were viewed as general competencies. The catalogue listing of these skills was developed to be used by curriculum developers to assist in the development of new programs. A second draft of the catalogue was published in 1987.

The Instructional Program Review (1985-1986)

As noted in the timeline presented in Appendix C, from November 1985 to April 1986, Alberta Education reviewed all core programs, including science, to see how well they matched the directions of the secondary education policy. Fifty-six major items were taken from the policy. Then a five-point scale (one; no emphasis to five; significant emphasis) was designed to measure how well each program covered the major items of the policy. Several committees comprised of classroom teachers, school administrators, university professors, and other interested members of the educational community contributed to the review. Committee members checked the standards, screened each program against the policy, and presented their findings. The recommendations for senior high science education were presented for internal discussion in a paper entitled *Proposed Directions for Secondary Science - Internal Discussion Paper* (Alberta Education, 1986c). This paper included recommendations related to the development of scientifically literate students and the characteristics they would possess, the senior high science program sequence, advantages and disadvantages of the proposal, program development considerations, and implications. Following the approval of this proposal, work on the new programs of study for senior high science began.

Secondary Education Action Plan (January 1986)

A plan was released for putting the secondary education policy into practice. It described instructional program developments (including general initiatives, programs and courses, and instructional program requirements), the process for designing instructional programs (including the set up of Implementation Advisory committees, program coordinating committees, and Ad Hoc committees) and implementation of instructional programs (including partnership opportunities, and professional development plans). These plans and more, came to fruition in the subsequent months as outlined below.

In May 1986, the Senior High Program Coordinating Committee was established to ensure that programs were consistent with policy statements and follow a logical sequence across and within subject areas. By September 1986, the first program manager for senior high science was appointed. The development process began with a review of secondary science curricula across Canada, a review of selected international curricula and related science education literature.

By October 1986, the program manager had drafted the *Proposed Directions for Secondary Science* (Alberta Education, 1986c). The proposal for change included the proposed program structure and the general directions for the science program. This internal document included sections entitled: the Rationale for Change, Current Status, Trends in Science Education, Proposal for Secondary Science, Program Development Considerations and Implications. The Program Development Considerations were discussed further under the sections entitled: Developmental/Cognitive, Required/Elective Balance, Critical Thinking, Essential Knowledge, Skills and Attitudes, Articulation with Junior High Science, Articulation with Post-secondary, Program Transferability, Relation of Science 10-20-30 to Specific Disciplines. The implications of these changes were discussed relative to: Program Acceptance, Consultation and Liaison, Development Timelines, Learning Resources, Inservice Strategy, Budget and Equipment and Provincial Assessment. The following proposals from this document proved to be controversial in the ensuing months: (1) the grade 11 subjects (20-level courses) were to be allocated twice as much time as previous 20-level science courses (2) an integrated science program was to be developed (Science 10-20-30) as an alternative to the traditional discipline subjects, and (3) the senior high science programs were to 'include an understanding of basic scientific concepts and their applications to our world'.

In February 1987, the Science 10-20-30 curriculum subcommittee was established (Alberta Education, 1987a) and the Biology 20-30, Chemistry 20-30 and Physics 20-30 subcommittees were established between March and May 1987. The subcommittees were composed of seven or eight teachers, one

Alberta Teachers' Association representative, and one post-secondary representative. Teachers were selected for committee participation from nominations submitted by their school jurisdictions to be representative of the diversity of schools and teachers across Alberta; public schools, separate schools, private schools, rural schools, urban schools, male teachers, female teachers, younger teachers, older teachers, and geographic representation. The tasks of these committees were to:

1. Select content statements, curriculum specifications, and criteria for resource selection.
2. Select initial learning resources for field testing.
3. Develop curriculum guides and other related documents. (Alberta Education, 1987a, p. 1)

These committees continued to meet over the following two years to develop the program. The processes of consultation and change that accompanied this process are referred to as Round 1 and are described in Blades (1994). The sequence is summarized here from the perspective of the events in Round 1 that influenced Round 2.

Proposed Directions for Senior High School Programs and Graduation Requirements (June 1987)

In June 1987, Alberta Education published a discussion paper called *Proposed Directions for Senior High School Programs and Graduation Requirements* (Alberta Education, 1987e). The paper discussed the changes to be made to senior high school programs in keeping with the secondary education policy. The paper then presented proposals for the content of programs, course sequences, credits for each course, and the timelines for introducing new and revised programs in schools. A few of the significant changes from the previous science programs to the new science programs included: (1) a general science course for all Grade 10 students, (2) the Science 20-30 program as an alternative to biology, chemistry and physics, and (3) and increase in the number of credits for Biology 20, Chemistry 20, and Physics 20 from three to five.

In October 1987, a mailout was sent to all senior high school principals, universities, educational associations, and other stakeholders requesting input into the proposed programs. The materials included: General Science Program Rationale and Philosophy Statement, a Draft Program of Studies for General Science 10-20-30, and a Response Guide for General Science 10-20-30. The concerns which emerged in the feedback included: (a) the scope of the proposed program was too broad, (b) a coherent format was absent, (c) there was too much material in the programs of study, (d) an appropriate textbook to support the programs did not exist, (e) funding to implement the program was perceived to be inadequate, (f) there would be inadequate teacher inservice, (g) there would be no flexibility in selecting electives and (h) the increased compulsory credits in science would put a strain on student programs.

School boards and administrators also responded to the proposed directions and the draft programs of study. They felt that the increased time allocation for science would make it very difficult for students to study other equally important subjects and receive a well-rounded education. By the spring of 1988, this influential group (composed of individuals educated largely in the humanities) convinced government officials to reduce the credits from 5 to 3. Following the announcement of the credit reduction in science, the academic scientific and engineering community united with the senior high science teachers to have the decision overturned. They also began to question the need for the general Science 10-20-30 program. The committees continued to meet and the programs of study were revised to accommodate the credit reduction.

As noted in the timeline in Appendix C, in October 1987, publishers were asked to submit potential basic learning resources. By December 1987, the resources had been reviewed and none of the resources had met the specifications for consideration as a basic text for Science 10-20-30. By May 1988, the Senior High Science Advisory committee and the Science 10-20-30 subcommittee had decided to accept the Gage publishing proposal. In April 1988, a field validation proposal was submitted to the Senior High Program Coordinating

Committee and Management Council outlining the proposed field validation plan.

Field validation of Science 10 was scheduled for September 1989 and implementation for September 1990. In July 1988, a new program manager was appointed. In September 1988, program consultants for Biology 20-30, Chemistry 20-30, and Science 10-20-30 were appointed. The program manager accepted the responsibilities for the Physics 20-30 program consultant. Also in September 1988, a new Minister of Education was appointed. These changes, in addition to the feedback from stakeholders such as that described below, contributed to a delay in the projected program implementation.

In April 1989, Alberta Education received a report from the Dean of Science of the University of Alberta entitled "*Report of the Faculty of Science ad hoc Committee on the Proposed Revisions to the High School Science Program*". It was a negative 15 page review including comments such as "The proposed Science 10-20-30 is not a good general science curriculum....The result is social science masquerading as science" and "We believe the science curriculum development should be primarily the responsibility of professional scientists and teachers educated and trained in science and science education. It must not be unduly influenced by professional educators whose backgrounds and interests, in science, are frequently secondary" and "we are concerned with the "watering down" of science in the school system." The appearance of this document and the publicity given to its contents (Blades, 1994) accelerated the decision to delay the implementation of the program.

The First Delay in the Implementation of Senior High Science Programs (April 1989)

On April 13, 1989, the Minister of Education informed schools that the senior high science programs would be implemented in schools one year later than expected in order to: "give science teachers, university staff, and other Albertans more time to look at the proposed programs and provide feedback; allow extra time to develop the Science 10-20-30 textbooks, and prepare support materials for teachers and students; and enable teachers to take advantage of workshops and programs that would help them offer the new science courses to their students" (Alberta Education, 1989b). Following the announcement of the one year delay, draft programs of study and response guides were again mailed out to various stakeholder groups, including all senior high schools, universities, educational associations and other Albertans, and their feedback was solicited. This occurred approximately the same time that the controversies over the credit reduction and need for Science 10-20-30 reached their peak. Over 200 letters were received from stakeholders, including the science teaching profession, universities, business and industry, expressing concerns with the new science programs. Due to the overwhelmingly negative response to these draft programs, in the summer of 1989, the controversy over the new proposed senior high science programs forced the Minister of Education to set up a special Minister's Advisory Committee on High School Programs to review the main issues of the controversy (Alberta Education, 1989c).

The Second Delay in the Implementation of Senior High Science Programs (January 1990)

The committee met from August 1989 to January 1990. On January 26, 1990 the Minister made the following announcement:

- The government would proceed with the development of Science 10-20-30 as a challenging, integrated, academic program with a focus on scientific concepts and skills fundamental to biology, chemistry, physics and other sciences. Science 30 was to be a 'rigourous, academic course that had content in common with Biology 30, Chemistry 30 and Physics 30'. A diploma examination for Science 30 would be developed to certify the achievement of students in the course.
- The government would revise the content of Biology 20-30, Chemistry 20-30 and Physics 20-30 so as to better prepare students for post-secondary studies and careers in science. The time allocated for Science 20, Biology 20, Chemistry 20 and Physics 20 would be 125 hours (5 credits).

- The government would involve science teachers, post-secondary institutions and professional associations in the development of the new science program and in pre-service and inservice opportunities for teachers. Universities, other post-secondary institutions, professional groups and the private sector were expected to help teachers build 'on their knowledge of science and ways of teaching science'.
- The government would ensure that more students became interested in science, especially young women. Teachers and counselors were asked to explore means to encourage more girls to take science and to consider careers in science (Alberta Education, 1990a).

The rationale for Round 1 included integration of the nature of science, the nature of technology, and science/technology/society interactions through a series of connecting topics. However, units such as the importance of water, personal energy systems and product evaluation did not receive professional and public acceptance and were replaced by discipline units which were tied together by themes of energy, matter and change. TABLE 4.1 presents an outline of the units of study proposed in Round 1 compared to Round 2.

TABLE 4.1 Comparison of Science 10 Unit Outlines in Round 1 and Round 2 of the Development Process

Science 10 Round 1	Science 10 Round 2
Unit 1 - Body in Balance	Unit 1 - Energy from the Sun
Unit 2 - Formation of Scientific Models	Unit 2 - Matter and Energy in Living Systems
Unit 3 - Importance of Water	Unit 3 - Matter and Energy in Chemical Change
Unit 4 - Personal Energy Systems	Unit 4 - Energy and Change
Unit 5 - Product Evaluation	

The reader is referred to Blades (1994) for a detailed description of the political nature of the process which led to the demise of the programs of study in Round 1 of the development process. Although some of the components from Round 1 carried over to Round 2, the process became more complex. Alberta Education could not afford to make the same mistakes in Round 2 as emerged (somewhat unexpectedly) in Round 1.

As seen from the preceding chronicle of events, curriculum development in today's educational environment is a complex matter. Both structural components and patterns of communication emerge as crucial to the development process viewed in a broad context. In other words, curriculum development is not confined to the production of documents and course outlines. It also involves aspects of communication, acceptance, perceptions of change and value orientations and numerous special interest groups.

To this point, the main focus of the curriculum development process had been on the development of the programs of study. Without support, for the programs of study, textbook development, resource identification and inservice plans could not proceed. However, these components would become additional focal points in the second round of development. It had also become apparent that the consultation and communication patterns (another major component of the development process) needed significant revision if Round 2 were to have a hope of succeeding. My thesis question is at this point partitioned into two sub-questions in order to allow me to analyze these aspects of the curriculum development process in more detail.

Thesis Question 1.1

What are the interrelationships between the components of the curriculum development process?

My account of Round 2 of the development of the senior high science programs is constructed to parallel (as much as possible) the program development cycle described earlier in this chapter. The first phase, the provincial review of education, and the second phase, the initial proposal were described earlier in this chapter.

Development of the Programs of Study in Round 2

As noted in the timeline in Appendix C, in January 1990, the Science Team started anew. With the decision that all senior high science courses would be 5 credits, Science 10-20-30 had to be completely revised, the consultation process would be expanded and the implementation plan (including the field validation plan) was completely revised. The Science Team began by formulating the vision statement, consulting stakeholders and garnering support. As the stakeholders were consulted about the vision they were asked to make all subsequent comments and feedback congruent with the vision. Once stakeholders were committed to the direction of the proposed changes, the design framework could be elaborated (Interview with Program Manager, 1997).

Design Framework of the Current Senior High Science Programs of Study

A similar conceptual and thematic revision was carried out in all of the current senior high science courses resulting in a common design framework. Each of the courses or programs of study is introduced with the Vision Statement for the Senior High Science Programs. This is followed by the Program Rationale and Philosophy, the General Learner Expectations, the Specific Learner Expectations and Basic Learning Resources. Appendix D presents the Science

10 Course of Study, and excerpts from the Science 20-30 Program of Study and the Chemistry 20-30 Program of Study. Each of these components will be described in turn.

The first section in each program of study consists of the Vision Statement. The vision statement identifies a common philosophical position for all the new science courses, with their components of student knowledge, skills and attitudes. It explains how the major thematic ideas of science (change, diversity, energy, equilibrium, matter and systems) are to be used to focus student learning on major concepts that transcend and unify the sciences. An active learning and problem-solving approach is outlined, along with the goal of fostering an enthusiasm for lifelong learning in science. The student-centered nature of the programs is highlighted with reference to the need to make the learning meaningful to students by providing appropriate contexts.

The Program Rationale and Philosophy section is also common to all of the programs of study. This section also presents the goals of the course and an overview of the course or program. The program rationale and philosophy is followed by the General Learner Expectations which are broad statements of science attitudes, knowledge, skills and science, technology and society (STS) connections that students are expected to achieve in all of the senior high school science programs. The program general learner expectations are further refined through the course general learner expectations and then developed in specific detail through the study of individual units in Science 10 and each of the sciences at the 20- and 30-level. All expectations follow a progression from Science 10 through to each of the 30-level sciences, and though listed separately, are meant to be developed in conjunction with one another, within a context (Appendix D Science 10 Course of Study, p. 3). The programs of study then outline the Specific Learner Expectations. This section includes a description of the learning cycle, a course overview and the specific learner expectations for each unit. The learning cycle outlines a stepwise constructivist sequence of course presentation derived from current research in learning and cognition. The last section of the programs of study list the basic learning resources.

One organizing structure which provides coherence within and between the course units and programs involves the use of **themes**. The course overview outlines the specific themes which are emphasized in the course. Each course emphasizes a subset of six broad themes which taken together organize and unify the current senior high science programs. The Course Overview states the units of study and provides a brief description of the units of study (Appendix C, Science 10 Course of Study, p. 9). Each unit is introduced with an overview of the themes investigated in the unit, a description of how the unit builds on previous learning, the major concepts to be developed in the unit, skills to be developed in the unit, STS connections to be illustrated in the unit and attitudes to be encouraged in the unit.

Science for All Americans, (AAAS, 1989) was published, about the same time that the Alberta Education Science Team faced Round 2 of the curriculum development process. This document presented recommendations about thematic ideas and how they apply to science, mathematics and technology. Thematic ideas are viewed as ideas that transcend disciplinary boundaries and prove productive in explanation, in theory, in observation and in design. The themes identified by AAAS were systems, models, stability, constancy and change, and scale (AAAS, 1989).

The thematic ideas presented in *Science for All Americans* provided ideas for selection of themes by the Science Team into the six themes presented in TABLE 4.2 Alberta Senior High Science Themes and the general learner expectations of the senior high science programs of study. The current senior high science programs use the themes to integrate concepts and facts in the units, courses and programs of study.

TABLE 4.2 Alberta Senior High Science Themes (Alberta Education, 1990c)

Change	how all natural entities are modified over time, how 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 that drives much of what takes place in the Universe through its variety of inter convertible 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.

Themes are considered useful in an integrated science program. Incorporation of themes allows for both the integration of units within a course of study and between courses of study. If students can (with the assistance of the teachers) see the integration of how parts of what they are learning fit logically, they may be better able to understand how the content is useful in explaining seemingly diverse phenomena. In an integrated science curriculum such as Science 10-20-30, many opportunities exist to show how the individual disciplines are connected by thematic strands (Alberta Education, 1990c).

A second organizing structure within and between the courses of study involves the concept of curriculum **emphases** (Roberts, 1988). The emphasis pertains to the contexts for learning a particular set of scientific concepts and is embedded within the concepts, skills and attitudes outlined in the program of studies. The emphases become more explicit in teaching as the content and context are blended. The three curriculum emphases are presented in TABLE 4.3.

TABLE 4.3 Alberta Senior High Science Curriculum Emphases (Alberta Education, 1990c).

Nature of Science	Distinct patterns in the physical activities and mental operations of scientists at work reveal the nature of science as a unique way of seeking knowledge
Science and Technology	The application of science and technology to solve problems or to advance one another demonstrates the interdependencies between science and technology
Science, Technology, and Society	Science is practiced in a context of human culture and, therefore, dynamic interactions occur between science, technology and society

These emphases are reflected the General Learner Expectations Connections Among Science, Technology and Society section of the programs of study (presented in Appendix D Science 10 Course of Studies, p. 3).

The specific learner expectations (SLEs) are further expanded within each unit. The SLEs are designed to be read with facing pages laid out side by side: with the major concept on the left and the STS connections on the right. Each major concept is subdivided into knowledge items (represented by •) and the associated skills and STS connections. A particular skill may relate to one or more knowledge item. The STS connections provide a variety of contexts for learning the knowledge and skills. The field validation drafts of the programs of study did not have the "or" statement between each STS connection and the "any other relevant context" statement. Field validation teachers reported that it was too much to expect of students to incorporate all of the knowledge and skills into each STS context. They also reported that there was no flexibility to bring in local or new contexts. The "or" statement and "or any other relevant context" was added to all programs of study in 1993.

Though some specific content overlaps between the disciplines, the greatest overlap in content occurs between each discipline and the general science program. For example, the nervous system and genetics are taught in Biology 30 and Science 30, acid-base chemistry is taught in Chemistry 30 and Science 30 and field theory is taught in Physics 30 and Science 30.

For a particular course of study the specific learner expectation skills are related to the general learner expectation skills and the specific learner expectation STS connections to the general learner expectation STS connections. For example, the skills emphasized in Science 10 are collecting and recording, organizing and communicating, and analyzing. These skills increase in complexity within the course from Unit 1 to Unit 4. For example, in Unit 1 students "observe and record physical properties of water" (Appendix D, Science 10 Course of Study, p. 13). By Unit 4, students are "conducting an investigation in which efficiency of common technological devices used to heat specific amount of water is quantified and evaluated" (Appendix D, Science 10 Course of Study, p. 47). These skills further increase in complexity between courses from Science 10 to Science 30. In Science 30, the specific learner expectation skills emphasize analyzing, connecting, synthesizing and integrating and evaluating. For example, in Science 30, Unit 4, students must design, carryout and evaluate an experiment to investigate the factors influencing the output of an energy conversion device (Appendix D, Science 20-30 Program of Study, p. 85). One reason for the placement of the 'physics unit' near the end of the course of studies was to maximize the development of mathematics skills since frequently mathematics is taken concurrently. The exception was Science 30. The 'physics unit', unit 3 was still placed late in the course, however, Unit 4, Energy and the Environment, was placed at the end of the course in order to maximize the integration of concepts from other units. For example, when students discuss issues related to energy production and alternate energy sources, they can discuss the impact of the energy source on human body systems, the chemistry of the environment and the physics principles related to the production of energy. Complexity of skills such as graphing, mathematical manipulation of equations spirals through the courses from unit 1 to 4. For example, in Science 10 unit 1, students should be able to "graph and analyze data showing how the density of water varies with temperature" (Appendix D, Science 10 Program of Study, p. 13) while in unit 4, students should be able to "calculate the area under a force-distance graph to determine work done" (Appendix D, Science 10 Program of Study, p. 41). The complexity of skills increases through to Science 30 as students should be able to "compare, graphically, the commercial potential of various renewable energy resources, such as solar power, wind power, hydroelectric power and biomass (Appendix D, Science 20-30 Program of Study, p. 85).

The STS connections generally spiral in complexity within a course and between courses. In Science 10, Unit 1, many STS connections begin with describe or explain (Appendix D, Science 10 Program of Study, p. 13) and in Unit 4, many statements begin with discuss, compare and contrast or analyze (Appendix D, Science 10 Program of Study, p. 45). In Science 30, many of the STS connections begin with assess and evaluate (Appendix D, Science 30 Program of Study, p. 83).

The Science 20-30 program was designed to articulate with the discipline-based courses. For example, in Science 20-30 some major concepts related to the discipline of chemistry include solutions, balancing equations, oxidation-reduction reactions, hydrocarbons, environmental chemistry, acids and bases, and organic chemistry. Chemistry 20-30 includes units of study on solutions, quantitative relationships, bonding, organic chemistry, thermochemical changes, electrochemical changes, equilibrium and acids and bases. The major difference between the programs lies in the depth of coverage. In Science 20 (Unit 3) and Science 30 (Unit 2) students get an overview of the discipline of chemistry by discussing these topics at the level of major concept. In Chemistry 30, a student studies each unit in much greater depth with an entire unit devoted to the topic and greater breadth by covering additional topics such as bonding and equilibrium. Excerpts of the Science 20-30 and Chemistry 20-30 programs of study are presented in Appendix D.

Identification and Development of Resources

Alberta Education identified and developed a variety of support materials to support implementation of the science, biology, chemistry, and physics programs of study. These resources could be grouped as resources created internally or within Alberta Education, those developed in consultation with Alberta Education and those developed externally by publishers or other outside agencies. A great deal of effort was extended by the Science Team to ensure that all resources identified or developed to support the implementation of the programs supported the program directions.

Resources Developed by Alberta Education

The following background documents for the senior high science programs were developed within Alberta Education: *STS Science Education: Unifying the Goals of Science Education* (Jenkins, 1990), *Teaching Thinking: Enhancing Learning* (Alberta Education, 1990) and *Focus on Research: A Guide to Developing Students' Research Skills* (Alberta Education, 1990). These three documents outlined some of the program thrusts which were incorporated into the programs of study, the *Senior High Science Teacher Resource Manual* (Alberta Education, 1991a), the inservice modules and the inservice sessions.

Teacher resource manuals (TRMs) and the background, exemplars and resources were also developed within Alberta Education. The *Senior High Science Teacher Resource Manual* (Alberta Education, 1991a) and the *Science 10 Teacher Resource Manual* (Alberta Education, 1991b) were developed for June 1991 so they would be available for the Science 10 inservice for field validation teachers. The purpose of the TRMs was to provide additional background about the revised science programs, support appropriate teaching strategies and present a list of resources (basic and support) useful to teachers when implementing the new science programs. Sections of the TRMs and, where applicable, their associated inservice workshops were contracted out to teachers and university education professors then reviewed, edited and revised by Alberta Education personnel. The Table of Contents for the *Senior High Science TRM* and *Science 10 TRM* are presented in Appendix E.

The background, exemplars and resources documents were originally intended to be the 20-30-level TRMs. However, as the political climate changed and Alberta Education decided to no longer publish TRMs (to a great extent because of budget restraints) these documents were cut from the budget line. Members of the Science Team had to argue that significant resources had already been expended in developing and field validating the documents that they should be finished and published. The political compromise was to change the name of these documents from TRMs to background resources and exemplars. The format of these documents is similar to the format of the *Science 10 TRM*.

Another group of resources developed by Alberta Education to support program implementation included the *Senior High Science Video Series*, the *Senior High Science Inservice Modules* (Alberta Education, 1991e) and the *Assessment Resource Packages* (Alberta Education, 1991f) for Science 10 and the 20-level courses.

The *Senior High Science Video Series* consists of 15 programs designed to facilitate implementation and to support the curriculum of new senior high science programs. Programs 1 and 2 describe the intent and content of the new programs and the continuity between junior and senior high science. Programs 3 to 5 are for inservice, featuring teachers using strategies supportive of the intent of the new curriculum. Programs 6 to 8 convey science concepts for students. Program 9 demonstrates the diversity of careers available in science. Programs 10 to 15 present short, single concepts in chemistry, physics and biology for students. A detailed description of the *Senior High Science Video Series* is presented in Appendix E.

The *Senior High Science Inservice Modules* (Alberta Education, 1991e) were designed to be half-day workshops for professional development of the senior high science teachers in topics consistent with the program thrusts. The *Senior High Science Inservice Modules* were generally written by the same contractors who wrote the corresponding sections in the *Senior High Science TRM.* A detailed listing of the *Senior High Science Inservice Modules* is presented in Appendix E.

A recurrent concern of the field validation teachers was a lack of assessment items for use with their students which reflected the intents of the new programs of studies (Romanyshyn, 1996). In response to these concerns, assessment resource packages for Science 10 and the 20-level courses were developed by Curriculum Branch, in conjunction with Science 10 field validation teachers and teachers experienced in item-writing with Student Evaluation Branch. These packages included multiple-choice and short answer questions provided some direction and a useful beginning for the field validation teachers.

The Student Evaluation Branch of Alberta Education conducts provincial diploma examinations for Science 30, Biology 30, Chemistry 30 and Physics 30. These help determine: (a) how well students have achieved the learning expectations in the science programs of study, and (b) if any changes should be made to the programs or the way they are being offered to students (Palmer, 1989). In Round 2 of the development process, a proposal for a 40-40-20 Evaluation Plan was briefly discussed. The proposal called for a broadening of the evaluation strategies consistent with the changes in the nature of the new senior high science program. The teacher awarded mark would count for forty percent of the student mark, the diploma exam would count for forty percent of the student mark and twenty percent of the student mark would be based on a project. The plan did not eventuate because a way of implementing the student project component in an equitable way could not be developed.

Resources Developed in Consultation With Alberta Education

As there were no general science texts which met the criteria for selection as a basic resource for Science 10-20-30, a publishing company was contracted to custom-develop textbooks for Science 10, Science 20, and Science 30. Although it was anticipated that a majority of high school students would take the Science 10-20-30 program route, the total population of Alberta students taking academic high school science is relatively small to justify the expense of a custom published text. This was one reason that only one textbook was made available for each course in the Science 10-20-30 program.

The custom-developed textbooks were developed in consultation with Alberta Education. Although the publishing company had the contract for writing and publishing the textbook, there were clauses in the contract outlining required changes and optional changes. Members of the Science Team (the program consultants) reviewed chapters of the textbooks as they were being written and consolidated feedback from the field validation teachers. Due to the commitment of the Science Team to try to ensure that the textbooks reflected the intended program directions, a great deal of time was spent making revisions to the textbooks (interview with Inservice and Implementation Consultant, 1997).

Alberta Education policy is that a new curriculum will not be implemented unless the resources (e.g., texts, teachers guides and teacher resource manuals) are available from the Learning Resources Distributing Centre by June 1 of the year of implementation (1992 for the implementation of Science 10). However, since the field validation year preceded the implementation year, the custom-developed textbook, the teacher resource manuals and other resources were subject to additional review and validation by the field test teachers during the appropriate field validation year. The specific sequence of events is presented in the timeline in Appendix C.

Resources Developed Externally to Alberta Education

The other group of resources identified to support program implementation were those that were developed externally to Alberta Education. These resources included print resources such as books, booklets, posters and kits and nonprint resources such as videocassettes, videodiscs, software, and laboratory interfaces.

Resource selection was a complex process. As detailed in the timeline in Appendix C, the first step involved a call to publishers to submit resources to Alberta Education. The call included a letter to publishers with guidelines about the type of resources which could be suitable for listing in the teacher resource manuals. These resources were submitted to Alberta Education and catalogued by the Learning Resource Unit. Then the resources were reviewed by an Alberta Education inservice and implementation consultant for curriculum fit and their appropriateness for use in Alberta classrooms. Some of these resources were in various stages of development which provided opportunities for modification to more closely match resource specifications; other resources were complete. These resources were either designated as basic, support, other, teacher or student or they were rejected for not meeting specifications. There was a particular focus on identifying resources to encourage the use of technology in the classroom. These resources included laboratory interfaces, laser discs, computer programs, test-generating programs, and bulletin board systems.

Professional Development

In Alberta, professional development is the responsibility of the school jurisdictions, the post-secondary institutions, and the Alberta Teachers' Association and implementation support is the responsibility of Alberta Education. The teachers themselves are also viewed as having the professional obligation to keep current with the new curricular initiatives in their area. However, the boundary between professional development and implementation support is blurred so in the following section, I use the term professional development to mean <u>all</u> of those activities which assisted in the implementation of the Alberta senior high science programs including the activities organized by Alberta Education (implementation support) and those activities organized outside Alberta Education (professional development).

In keeping with this division of responsibilities, a needs assessment of professional development activities was carried out. It identified the responsibilities of each of the stakeholders listed below (Alberta Education, 1990e).

Alberta Education would provide inservice for field validation teachers, provide model workshop modules to jurisdictions on request, and co-ordinate regional information sessions. Post-secondary institutions would be responsible for preservice science education, inservice science education such as special session, evening, distance education courses and summer research work programs for teachers. Professional organizations such as the Alberta Teachers' Association and the ATA Science Council would provide ATA Science Conference activities, regional science council activities, and organize professional development days and convention-related activities. The Alberta Professional Engineers, Geologists, and Geophysicists Association, Alberta Chamber of Resources, Alberta Research Council would sponsor and organize speakers bureau, sponsor summer research programs for teachers and fund and provide speakers and/or facilities for summer institutes. Regional consortia would identify local professional development needs, provide local solutions to local needs, set up support network for science teachers, forge partnerships with local business and industry, organize a regional curriculum resources bank and help set school goals for the science curriculum in consultation with teachers and administrators. Summer institutes would provide a "science immersion" experience and focus on the needs of the new science programs.

Field Validation

The curriculum development process described to this point involves the development of the programs of study and the identification and development of support materials. A key stage in the process involves the bringing of the curriculum as intended or as set out in documents and materials 'to life'. The dynamics of putting the curriculum in motion or into action with real teachers and students itself constitutes a complex process and sequence of events. A detailed account of this process related to the field validation teachers is presented in *Teachers and curriculum change: Examining inservice program implementation* (Romanyshyn, 1996).

The political pressure for the revised senior high science program development to succeed resulted in considerably more Alberta Education resources being allocated to the teacher inservice component of the senior high science project than had ever been allocated to previous curriculum field validation projects (Interview with Inservice and Implementation Consultant).

The selection of field validation school sites was a complex process as there had to be a representative sample of teachers and school environments from across Alberta. A field validation school was required to participate for the full three year project involving the field validation of Science 10 in 1991, followed by the field validation of the 20-level courses in 1992, and the 30-level courses in 1993. The Alberta Education expectation was that the science teachers at the accepted school(s) would provide on-going feedback allowing appropriate revisions to be made to the developing courses of study and resources and that they participate fully in the inservice program provided by Alberta Education.

School jurisdictions were invited to nominate particular schools within their jurisdictions to participate. Approximately 70 nominations were received. From these nominations, 35 schools from 29 school jurisdictions were selected. Approximately 135 teachers and 4600 students field validated the senior high science programs. A large field validation population was needed to ensure a large enough student population to field test future diploma examination items. Implementation of the courses for all schools in the province was in 1994, subsequent to the field validation year.

What were some of the advantages of participating in the field validation for a school jurisdiction? At the jurisdiction level, field validation teachers were expected to become an important source of professional leadership within the school jurisdiction, capable of assisting other teachers as they implement the new programs the following year. At a school level, schools were provided with class sets of the draft Science 10, Science 20, and Science 30 student textbooks, as well as new student textbooks for Biology 20-30, Chemistry 20-30, and Physics 20-30 which they would keep after the field validation. At a personal level, the teachers would be involved in the inservice activities over the three years of the field validation. In addition, those teachers piloting the 30-level courses would have the advantage of seeing the field test versions of the new diploma exams.

Inservice activities included background and updates on program development, workshops related to to program thrusts, field trips, guest speakers discussing spedific STS connections, planning sessions, new laboratory activities specific to each course and workshops on the use of technology in the science classroom. Again a detailed account of these activities is presented in Romanyshyn (1996).

The individuals attending the inservice activities included the Science Team, field validation teachers, administrators, curriculum consultants, inservice leaders, the diploma examination managers, the Regional Office of Education science consultants, Alberta Distance Learning consultants, and a language services program manager.

Prior to the implementation of the revised science programs, the model of curriculum implementation used extensively in Alberta for a number of years was the Cascade model. The Cascade Model is a top-down curriculum development, field validation and implementation process (Lantz, 1984). Generally the new resources would be piloted along with the new programs of study. It was expected that the field validation teachers, selected to be representative across the province, would form a nucleus of leadership for other teachers within their schools and jurisdictions and actively participate in helping prepare other teachers to implement the new program. Although this model is cost effective, it was not very effective in supporting science curriculum implementation (Romanyshyn, 1996). A more broadly constituted base for curriculum implementation seemed indicated.

For many senior high science teachers, curriculum supervisors and administrators, the first opportunity to become aware of changes to the senior high science programs was to attend zone meetings. These meeting provided an opportunity to find out about the proposed changes and discuss the implication of those changes. Information sessions offered in the spring of 1992, 1993 and 1994 provided a similar forum for discussion but tended to focus more on ways to assist the implementation of the new science programs. The 1992 information sessions focused mainly on Science 10, the 1993 information sessions on the 20-level courses and the 1994 information sessions on the 30-level courses. Participants were expected to bring information back to their various jurisdictions providing leadership in their area

In addition to the responsibilities discussed above, an extensive array of support materials was developed to assist all senior high science teachers with the implementation of the new science programs. Availability of support materials came as early as 1990, with the publication of the *STS science education Unifying the goals of science education* (Jenkins, 1990), *Focus on research* (Alberta Education 1990g) and *Teaching for Thinking: Enhancing Learning* (Alberta Education 1991b) and the first five videos of the Senior High Science Video Series (see Appendix E). Subsequently in 1991, the *Senior High Science Teacher Resource Manual* (Alberta Education 1991a) and the *Science 10 TRM* (Alberta Education 1991b)were made available and in 1992 the *Science 20-30 Background, Exemplars and Resources* (Alberta Education 1992c), *Biology 20-30 Background, Exemplars and Resources* (Alberta Education 1992d) *Chemistry 20-30 Background, Exemplars and Resources* (Alberta Education 1992e), *and Physics 20-30 Background, Exemplars and Resources* (Alberta Education 1992f) were made available. Other materials such as *Senior high science program implementation - Information and suggestions for administrators* (Alberta Education 1992a) and *Suggestions for teachers implementing Science 10* (Alberta Education 1992b) were included in packages mailed out to schools.

Post-secondary institutions were responsible for preservice science education and inservice science education. The involvement of the three major Alberta universities in the inservice activities of the field validation teachers served to assist post-secondary science educators for their task ahead and provide a direct line of communication between the universities and the Science Team.

The Alberta Teachers Association (ATA) and the ATA Science Council played a significant role in preparing senior high science teachers for the implementation of the science programs. Many teachers conventions and professional development days offered sessions designed to assist the implementation of the new senior high science programs. For example, some offered the senior high science inservice modules as workshop sessions, others brought in speakers to discuss new topics or relevant STS connections in the programs of study, or the use of technology in the science classroom. The ATA Science Council conferences provided another excellent opportunity for senior high science teachers to prepare for the implementation of the new science programs. The focus of the conferences was congruent with changes to the science programs as the conference theme from 1992-1994 was Science/Technology/Society.

Regional consortia became involved in offering professional development opportunities for teachers in their jurisdictions. Many of these sessions were similar to those offered at professional development days or conventions. Business/industry became involved in various types of partnerships with schools which were designed to be mutually beneficial. These partnerships included offering speakers to come to schools to present information on careers in science or topics in the curriculum or field trip sites.

A few organizations began to offer summer institutes, some of which were co-sponsored by a University offering course credits and business/industry or other agencies offering speakers or financial resources. Some of the summer institutes were similar to scholarship programs where teachers would apply and be selected to participate. Generally the institutes were designed to be generic or flexible enough so that teachers from grades 1-12 would be able to take useful materials or teaching strategies back to the classroom.

Members of the Science Team assisted with the organization of or participated in many of the professional development activities described above. This provided reinforcement fo the program directions and another mechanism of informal consultation and communication for the Science Team.

Since the implementation of the 30-level courses in 1994, relatively little has been done to "maintain" or "evaluate" the revised senior high science programs. Some work has been done to clarify or delete specific learner expectations in response to feedback from stakeholders, usually the diploma examination managers and teachers. Some resources, developed since the publication of the teacher resource manuals, have also been reviewed and information regarding suitable resources has been sent to schools. Formal evaluation of the senior high science programs has not occurred to date, although a review of the programs is scheduled to begin in 1997.

Student Evaluation Branch indirectly plays a role in the maintenance of the programs. Through documents such as the *Bulletin* and the *Examiner's Reports* future directions of diploma examination questions or clarification of depth of coverage of topics which may be tested and information about student performance on a particular diploma examination is published and distributed to teachers across the province. The exam managers also meet with teachers on a regular basis for item writing, field-test development, teacher validation and external review of the diploma examinations. This seems to provide another mechanism of reinforcement of program direction for the 'enacted curriculum'.

It is evident from the previous description of the development of the Alberta senior high science programs that curriculum development is a complex, multidimensional, and dynamic process involving numerous components and complex interrelationships. Three components (1) the development of the programs of study (2) identification and development of resources and (3) professional development, have been identified so far in this study. The following section will discuss the fourth component, consultation and communication, which emerged as central to the curriculum development process. It is central because the previous three components take place within the domain of the consultation and communication process.

Thesis Question 1.2

How do the patterns of communication and consultation influence the shape of a dynamically curriculum development model?

Consultation and Communication

In today's educational, social and political environment, the task for those involved in promoting educational change through the curriculum development process is more complicated than ever before. They must not only articulate the need for change, but also inform stakeholder groups and seek their support for the proposed changes. This means having a commitment to the reasons for change, and arguing in favor of change. This is a complex process. Both professional and public understanding and support is necessary if real change is to occur (Panwar, 1995).

Traditionally, in Alberta, several groups including Alberta Education staff, classroom teachers, administrators, school superintendents, consultants, post-secondary science and education instructors, school trustees, and other governmental agencies and departments have influenced what happens in education. In the case of the Alberta senior high science program development process, the sphere of influence was broadened as other stakeholders in science education became involved (see p. 57). Some of these interest groups used the media to influence politicians to change program structure and content (Blades, 1994).

My third research question addresses issues related to broadening the sphere of consultation throughout the curriculum development process. I will discuss who was consulted, what they were consulted about, and the interplay between internal patterns of consultation and communication and external patterns of consultation and communication.

Internal Consultation

Several groups within Alberta Education are consulted throughout the curriculum development process. Following the development of a framework for the programs of study, this framework was the focus of discussion at internal meetings involving representatives of various branches of Alberta Education at several levels. One of the first groups to provide input was the interbranch team, which includes the program managers and consultants from other branches such as Student Evaluation Branch, Alberta Distance Learning Centre, and the Regional Offices of Education. Since this group was made up of science educators, details such as scope, sequence of content and curriculum emphases were discussed. Feedback from these meetings would be incorporated into revised drafts and taken to subsequent meetings with Management Council. Management Council would take this information to Division Council which would subsequently take information to the Deputy Minister and the Minister of Education and relevant action items would be directed back to the Science Team. These groups were kept informed of the events of the development process and provided with numerous opportunities for input.

External Consultation

Once a framework was established, the process of external consultation could begin. Again there were several levels of consultation. The first level was the Senior High Program Coordinating Committee which included membership from within Alberta Education and stakeholders in education. The purpose of this committee was to coordinate all programs into a cohesive educational system. They would examine issues such as credit allocation and course sequence. Other committees included the Senior High Science Advisory Committee and the subject area sub-committees. The Senior High Science Advisory Committee (from Round 1) was composed of two science consultants, four teachers, a representative from Northern Alberta Institute of Technology, a principal, and a university faculty of education department head. This committee discussed course scope, sequence, emphases and the elective component (there was an elective component in the original program outline), development, field testing and implementation timelines, goals and objectives of the science programs. The committee provided input into the program outline, selection and development of resources (Alberta Education, 1988c). As the program development continued, the committee provided feedback on the developmental frameworks, programs of study, senior high school graduation requirements (Alberta Education, 1988d) and provided input into teacher inservice and issues pertaining to the development and implementation of the new programs (Alberta Education, 1988f).

The revised program outline became the focus for discussion at subject area sub-committee meetings. These committees were composed of eight teachers, one Alberta Teacher Association representative, and one post-secondary institution representative (Alberta Education, 1988b). The teachers were selected for committee participation from nominations submitted by their school jurisdictions to be representative of the diversity of schools and teachers across Alberta as described earlier in this chapter. As noted, these committees considered specific detail about scope and sequence of topics in the programs of study. Several meetings were held alternating between the Senior High Science Advisory Committee and these sub-committees as newer drafts of the programs of study emerged. Other stakeholders were consulted through mailouts and meetings. Much of the feedback regarding the program changes was negative as was described earlier in this chapter.

When it became apparent that the initial curriculum plan was not viable, a major re-thinking and revision of the patterns of communication and consultation was initiated. External consultation began anew with the establishment of the Minister's Advisory Committee on High School Science Programs in the summer of 1989. The previous Senior High Science Advisory Committee was replaced when the Minister established this new broadly representative committee including many of the strongest critics to the original programs. This "blue ribbon" committee was comprised of the Minister of Education, the Assistant Deputy Minister of Student Programs and Evaluation, two science teachers representing the Alberta Teachers' Association, a representative of the Association of Professional Engineers, Geologists, and Geophysicists of Alberta (APEGGA), a member of the board of the Energy Resources Conservation

Board, a representative of the Conference of Alberta School Superintendents (CASS), a representative of the Alberta Medical Association, the program coordinator of the Mathematics, Physics and Computing Department at the Southern Alberta Institute of Technology (SAIT), the president of the Calgary Chamber of Commerce, a professor from the Faculty of Education at University of Lethbridge, the chairman of the Department of Microbiology in the Faculty of Science at the University of Alberta, the Department Head of Curriculum and Instruction in the Faculty of Education at the University of Calgary, a representative of the Alberta Federation of Home and School Associations, a representative of the Department of Academic Development from Grande Prairie Regional College, and a representative of the Alberta School Trustees Association.

The committee's role was to provide ongoing consultation on content and structure of the revised program, the recommended resources and the initiatives that were being planned to support the program. They were also to provide advice to the Minister on policy matters related to the new science programs for grades 7-12 as they looked for consistency of the developing curriculum with the existing policies. The committee also provided the Minister with a forum to communicate the nature and the intent of the revised secondary science programs to the public, and to professional and educational associations that had been critical of the work done to date.

Following the announcement of the second one-year delay in January, 1990, the public consultation process expanded and the program revisions formally began. Panwar (1995) states that these stakeholders became part of a province-wide network for sharing information and ideas. The Science Team was responsible for providing information on opportunities for stakeholder input and for establishing a response system to deal with new issues and problems quickly and effectively. To manage the process of receiving advice from both internal and external groups, the responsibilities of each group were clearly stated. While internal committees such as Division Council and Management Council reaffirmed the general policy directions, the subject area sub-committees and science educators provided answers to specific questions related to 'basic scientific concepts' and 'essential scientific skills'. Each group was made to understand which role they were invited to play.

Inevitably consultation with multiple stakeholder groups resulted in conflicting or competing demands being made by different groups. One way to deal with these demands was to bring stakeholders together at meetings held across the province. The timeline in Appendix C details the meetings that were held. Issues would be debated and the Science Team would be left to make final decisions while considering input from multiple stakeholders.

Once stakeholder groups recognized the need to deal with competing demands, they were ready to consider a common vision. This was a key stage in the consultation process To facilitate the development of a common vision, the groups were asked to focus on the following questions:

- What comprises success in science for the student and for society?
- What are the elements of that success and how are they interrelated?
- What knowledge, skills and attitudes should be included in the programs if students are to be equipped with a good knowledge of science for further study in science and career preparation, and to become informed decision makers? (Alberta Education, 1990h)

The vision document which was created (see Appendix D Science 10 Program of Studies p.1-2) helped to focus the discussions about the selection of science knowledge and skills to be included in the programs and courses. Panwar (1995) states that the inclusion of STS connections in the program vision was done in the full knowledge that only some influential science teachers would support it, and that some academic scientists would not. Nevertheless, the Science Team made the decision to include STS connections. A reduced form of the original plan for STS that was accepted as a solution to the conflicting demands.

The first round of the Alberta senior high science program development did not fully realize the extent to which the educational, social and political environment had changed from earlier times, when top-down expert-prepared curricula were accepted with little professional and public comment and criticism (Kass, 1991).

Hence, a strong advocate for and commitment to the change was not established. A valuable lesson was learned by the Science Team as they faced Round 2. Media attention established political need for the proposed change. Through the Minister's Advisory Committee on Senior High Programs, critics were heard and became less vocal as they saw that their views were heard. An extensive field validation and implementation plan was proposed and supported by a commitment of resources and action. Clearly, a greater sensitivity to the need for clear and sustained two-way communication among the public stakeholders, Alberta Education and the teachers was a positive outcome of the earlier difficulties. As a response, communication and consultation patterns grew in scope and complexity both at the internal and external levels of program development and implementation. Perhaps inevitably the overall program became somewhat more conventional in its focus. Nevertheless some important changes were retained and continue to be refined as teachers and students enact the curriculum.

CHAPTER 5 COMPONENTS OF A CONTEMPORARY CURRICULUM DEVELOPMENT MODEL

The program development cycle described early in Chapter 4 represents a simplified version of the curriculum development model designed to be followed by Alberta curriculum developers. It implies that the curriculum development process is linear when in reality it is a complex and recursive process. My analysis of the events in Chapter 4 has revealed several interacting components of curriculum development in a complex, multidimensional and dynamic environment. The model I have portrayed in this chapter is not intended to prescribe order or sequence. The curriculum development process is intended to be viewed as a holistic process. I am attempting to present the curriculum development components and the complex inter-relationships which were described in Chapter 4 in a sequence of nested models and sub-models. The set of embedded models presented here is one portrayal of the complexity of contemporary curriculum change - there are other ways to portray this data. The models are presented in sequence from general to specific and in a sequence consistent with data presentation in Chapter 4.

The representations constituting the model and submodels were discussed in two interviews with members of the Science Team. One interview was with the Senior High Science Program Manager and the other interview with the Inservice and Implementation Consultant in charge of the teacher resource manual development, organizing the field validation teacher inservices and other implementation support activities described in Chapter 4. Present at the interviews were the interviewee, my supervisor and myself. A list of the interview questions (presented in Appendix F) and a draft copy of Chapter 5 of my thesis were given to each interviewee prior to the interview. The questions were organized to elicit response to the model and submodels presented in this chapter. The Program Manager was asked to comment on all of the submodels because of his leadership role in the development process. The Inservice and Implementation consultant was asked to comment on the model and the submodels pertaining to resources, professional development and the models representing consultation and communication. Excerpts from the transcribed interview are presented in Appendix F. The interviewees were designated R and B, my supervisor was designated H, and I was designated D.

Alberta Senior High Science Curriculum Development Model

Figure 5.1 portrays the interrelationships among the main components of the curriculum development process. The consultation and communication process is placed at the center to emphasize the importance of this component to the curriculum development process. One may consider the domain of the consultation and communication process in an expanded way as encompassing the components positioned at the outer regions as well.

The activities which take place within the domain of the curriculum development process have been categorized into four components: (1) development of the programs of study, (2) identification and development of support resources, (3) professional development, and (4) consultation and communication. The first three components take place <u>within</u> the consultation and communication process. I have depicted the aspects related to the development of the programs of study by using solid rectangles. The aspects which are more closely related to implementation, that is, the identification and development of resources and professional development, are depicted using ovals and rectangles with rounded corners.

Each of these components is interrelated through the curriculum development process. For example, the curriculum development process results in the programs of study which require professional development and identification and development of support resources. Through consultation, feedback related to or issues arising from one component may affect one other component or, more likely, may affect all other components. For example, if a topic such as organic chemistry had been deleted from Chemistry 20 there would be a ripple effect through other programs of study. Organic Chemistry would have to be moved to Chemistry 30 or sufficient background would have to be taught in order to develop concepts in the units of thermochemistry and acids and bases in Chemistry 30. The Science 20-30 Program of Studies would also be affected

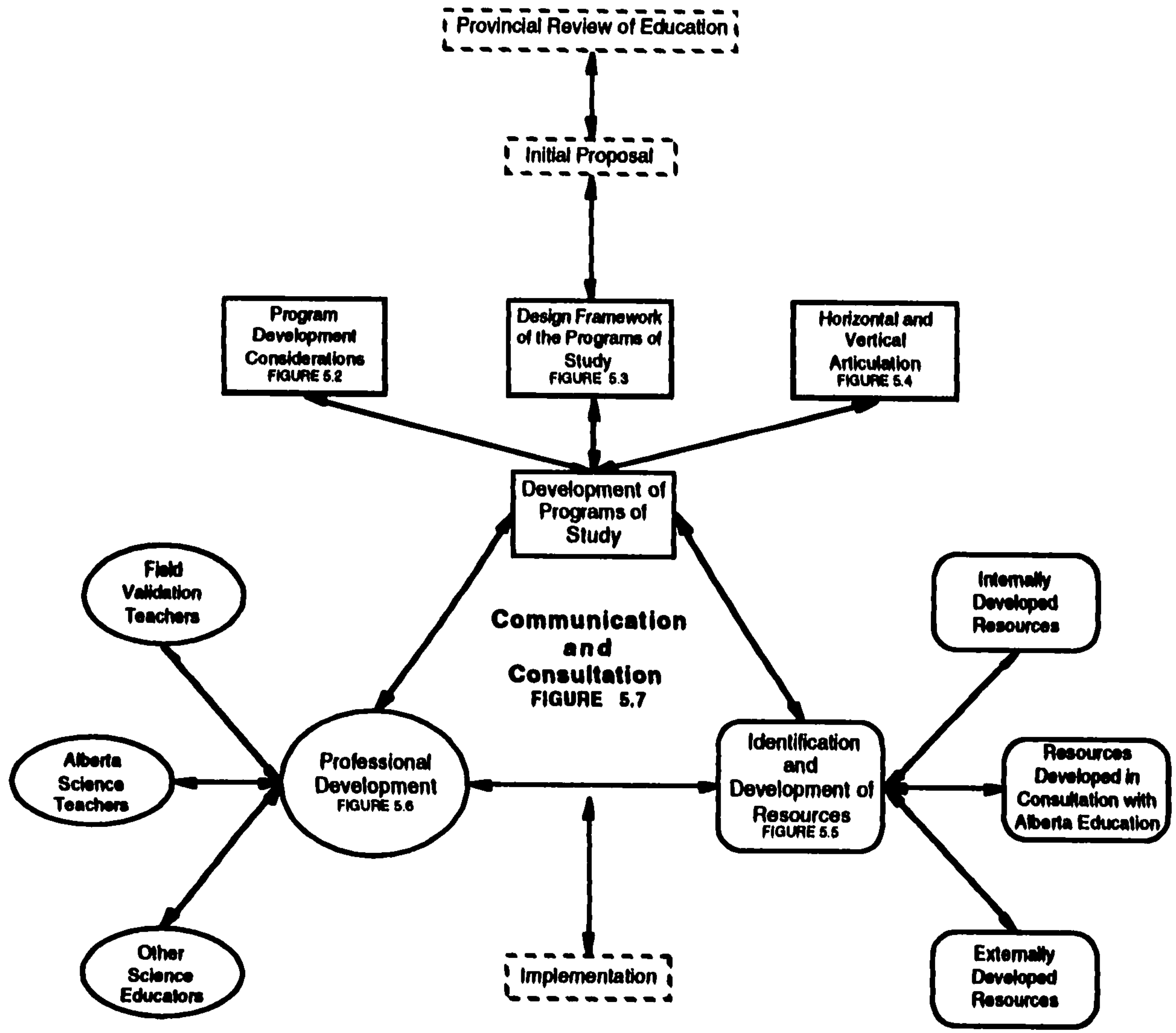

FIGURE 5.1 Components of the Alberta Senior High Science Curriculum Development Process

since major concepts in Science 20-30 articulate quite closely with units in Chemistry 20-30. Deleting organic chemistry from Chemistry 20 would also influence how topics are sequenced and treated in Biology 20-30 since some topics in Biology 20-30 such as cellular respiration or the digestive system require some background in organic chemistry. The basic resource could change (depending on the stage of development of the resource) because the concept is no longer taught in the course or it is taught at a different level in a subsequent course. The resource list in the teacher resource manuals (TRMs) would change because there is no sense in listing resources for concepts which are not covered in the programs of study. Professional development activities such as the demonstration of laboratory activities (done at the ATA Science Council Conferences and information sessions) related to the concept change would have to be modified. Finally, stakeholders would have to be consulted regarding the changes to the affected programs of study. This example is hypothetical but it serves the purpose of illustrating the interrelationships of the components of the curriculum development process.

In both the interview with the Senior High Science Program Manager and the interview with the Inservice and Implementation Consultant, the interviewee was presented with FIGURE 5.1 and interview question 1 **What do you consider to be the most important component of the curriculum development process?** The Program Manager made some preliminary remarks and identified the consultation and communication process as central.

R: I have always looked at the development process of curriculum to have two major components: small p political and big p, Process. You must be able to straddle both the political world and the process world. In the political world, you need to craft a sense of vision, then you have to show that you have support for the vision and then you have to have a real commitment to making that particular change. In order to secure those kinds of support for a curriculum development process, you have to go out and talk to people.

H: In other words, the consultation and communication components are very important?

R: Yes, and you have to have a very clear idea as to what it is that you want to go about achieving and then how do you marshal resources and support in order to achieve those particular goals.

It is not just something you do outside of Alberta Education...you also have to do it within the Ministry as well.

The Inservice and Implementation Consultant also identified consultation and communication as key elements of the curriculum development process as she responded to question 1.

R: I think from my perspective it would be the communication and the consultation process which I feel that none of the other things would have been near as successful if there hadn't been such effective communication and consultation ...

The Program Manager went on to describe what he referred to as "process". Part of this view of process is similar to what Schwab (1970) calls the 'eclectic'. In other words, selecting and using the best from various sources. He also stressed the importance of creating a team that can go about delivering the product called a curriculum.

R: The second aspect, the process aspect, I will use the term loosely as a technical process. You have to have a real good knowledge of what curriculum is, what curriculum development is, you have to have a really good sense of what curriculum trends are around the world. You have to have a library of resources you have to accumulate- whether it be documents from other parts of the world, other forms of curricula and then you have to, of course, create a team that can actually go about delivering this product or this artifact called a curriculum, curriculum study, curriculum guide or program of study.

H: So what I hear you saying is that process has two components; contextualization in trends and emerging issues and so on.. and the other thing you mentioned was an assembly of personnel...

R: Yes they are ... fundamental to both is the ability to communicate what it is you are trying to do and then try to find a process by which we are going to achieve those results.

He also further elaborated on FIGURE 5.1:

R: This diagram does a very good job of putting the pieces together because clearly in this province...we are committed, from a policy point of view of ensuring that our programs of study and the resources that we have, ... that there is a high degree of match between the two of them, so that having this team of people that

> was working on the senior high science programs, they were also the folks involved in identification and development of learning resources...The belief that we have is that while you can have learning expectations statements here and yes, they have the force of law, clearly we want to make sure that when you are making a big change...We need to make sure that there was some support through resources...

Both the Program Manager and the Inservice and Implementation Consultant agreed that FIGURE 5.1 accurately portrays the interrelationships between the components of the current senior high science curriculum development process in Alberta.

Development of Programs of Study

As noted earlier, FIGURE 5.1 is further developed in a sequence of sub-models. The group of figures which follows presents more specific aspects of the development of the programs of study.

FIGURE 5.2 presents the **Program Development Considerations**. I have separated these considerations into two general areas of influence. One area reflects societal and philosophical influences. The second is directed at influences on the student and the learning environment. I have tried to portray in a geometric way the influence each program development consideration had on the programs of study through proximity and emphasis (bold). The closer the program development consideration to the programs of study, the greater the influence and the greater the emphasis.

Of the societal and philosophical influences, developments in science and science education, the changing needs of society in Alberta, and provincial policy directions are portrayed as having the greatest influence. The results of the *Review of Secondary Programs* (Alberta Education, 1985a) indicated a need for change in education. This, combined with a strengthening of the STS movement in science education and a more multidisciplinary approach in the science disciplines, prompted the revision of the Alberta science programs. The goals of schooling and the goals of education are portrayed as having a somewhat weaker influence on the programs of study. These goals are not

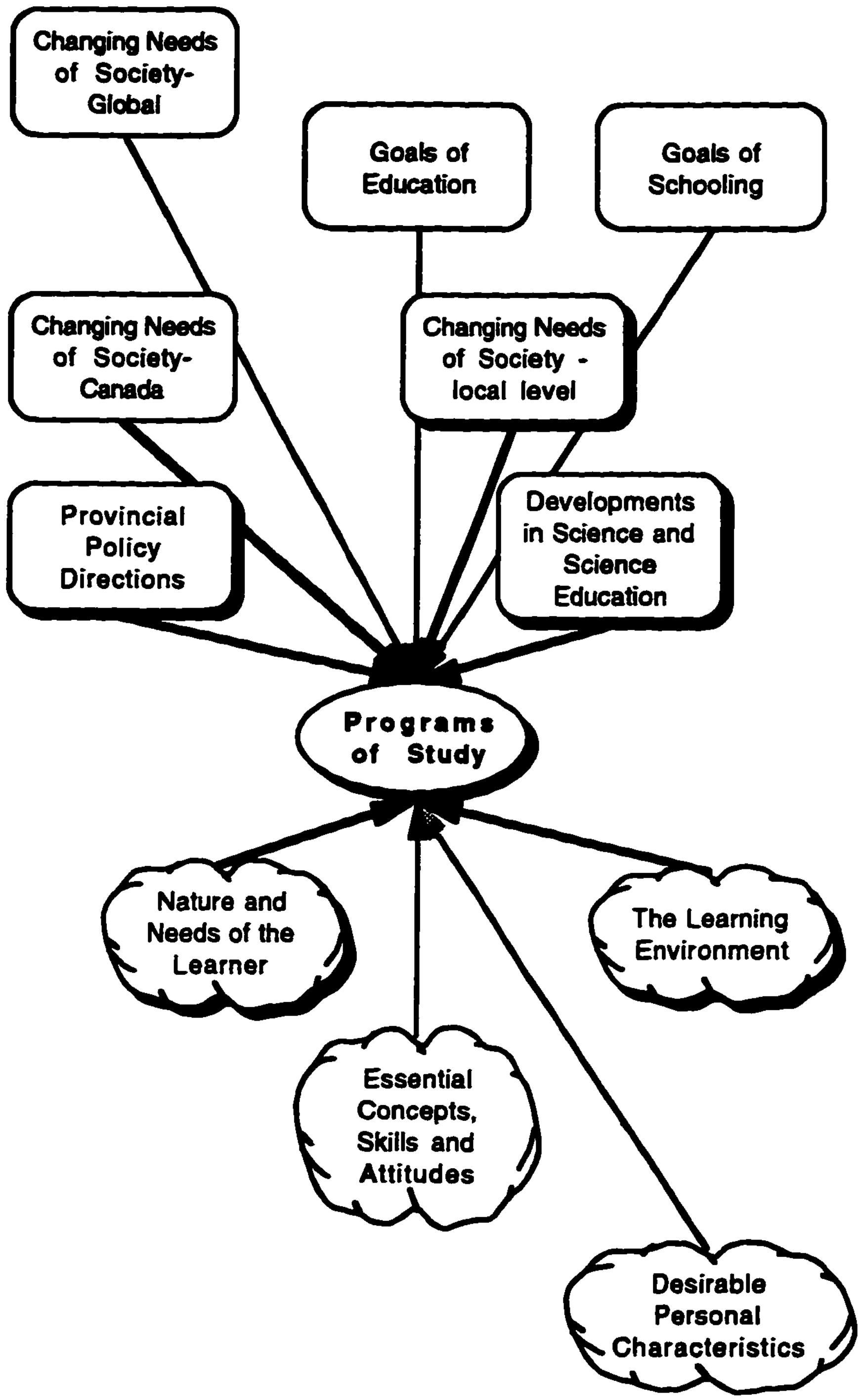

FIGURE 5.2 Program Development Considerations

stated directly in the programs of study but the programs of study are consistent with these goals.

Of the student and learning environment influences, the nature and needs of the learner and the learning environment are portrayed as having a strong influence on the programs of study. For example, the programs of study state that "students are expected to participate in their own learning" (Appendix D Science 10 Course of Studies, p. 1). Through the process of internal validation the developmental needs and abilities of students were addressed in the sequencing of the concepts in the programs of study. The *Senior High Science Teacher Resource Manual* (Alberta Education, 1991a) addresses aspects of the learning environment through a variety of teaching and assessment strategies such as teaching for thinking, cooperative learning, focus on research, peer assessment, self-assessment and portfolio evaluation. The development of desirable personal characteristics is something that is less tangible. Whether this has been accomplished is something that is difficult to measure or monitor or evaluate. Although the development of desirable personal characteristics was incorporated into the programs of study, it is found implicitly rather than explicitly.

The Program Manager was presented with FIGURE 5.2 and question 2 **Would you regard the proximity placement of the components as appropriate to represent the influence they had on the programs of study?** He quickly checked off the items of greatest proximity to validate their position of influence and elaborated:

R: ...this diagram does portray our considerations at the start and toward the end (of the development process). In other words, goals of education didn't suddenly become more paramount than this...just because these things are distant doesn't mean that they weren't used or that we hadn't picked them up via osmosis or some other means. So if you take a look at the documents, there is a clear relationship going back to them, but did we actually sit down and say, "here are the goals of education and let's see how we can incorporate them?" No, we saw them as supportive materials, but our, my centrality was here. (He pointed to the "developments in science and science education" program consideration.)

His comment reaffirms the notion that the curriculum development process is holistic in nature and that many dimensions are considered both implicitly and explicitly.

FIGURE 5.3 portrays the **common design framework** shared by all senior high science programs of study (Science 10-20-30, Biology 20-30, Chemistry 20-30, and Physics 20-30) which was discussed in Chapter 4. The Program Manager was presented with FIGURE 5.3 and question 3 **What was the purpose of the similar design framework among the programs? That is to say, what did it emphasize?** He commented that one of the reasons for this common design framework was the overlap between the skills, STS and attitudinal expectations between the subject areas.

R: ...Here we were given a fabulous opportunity to develop all of these programs at the same time. So we asked ourselves, what is the best possible design for science education? And when you think about the components, of what goes into science education, we are always going to have skills expectations, we are going to have STS expectations, we are going to have some attitudinal expectations and then we are going to have some knowledge expectations. Right? Well, given that there is so much overlap between three of the four, we figured, why don't we give it the same design frame? Why don't we then try to level, as much as possible, the standard as expressed by the expectation statements (we call them curriculum standards) and do that across the board for the different subject areas? And then, wherever appropriate, you could then contextualize and weave in the knowledge portions as much as we could.

H: So you basically move the design framework from within a discipline and those considerations into a larger, more inclusive design framework?

R: Exactly!

A similar format also facilitates the perception of equality among the programs so that none of the subjects appear more or less academic than any other subject. This was an important consideration as the Science 20-30 program was viewed from the outset of development as being "less academic" than the discipline-based programs. By presenting all courses in a similar format to the

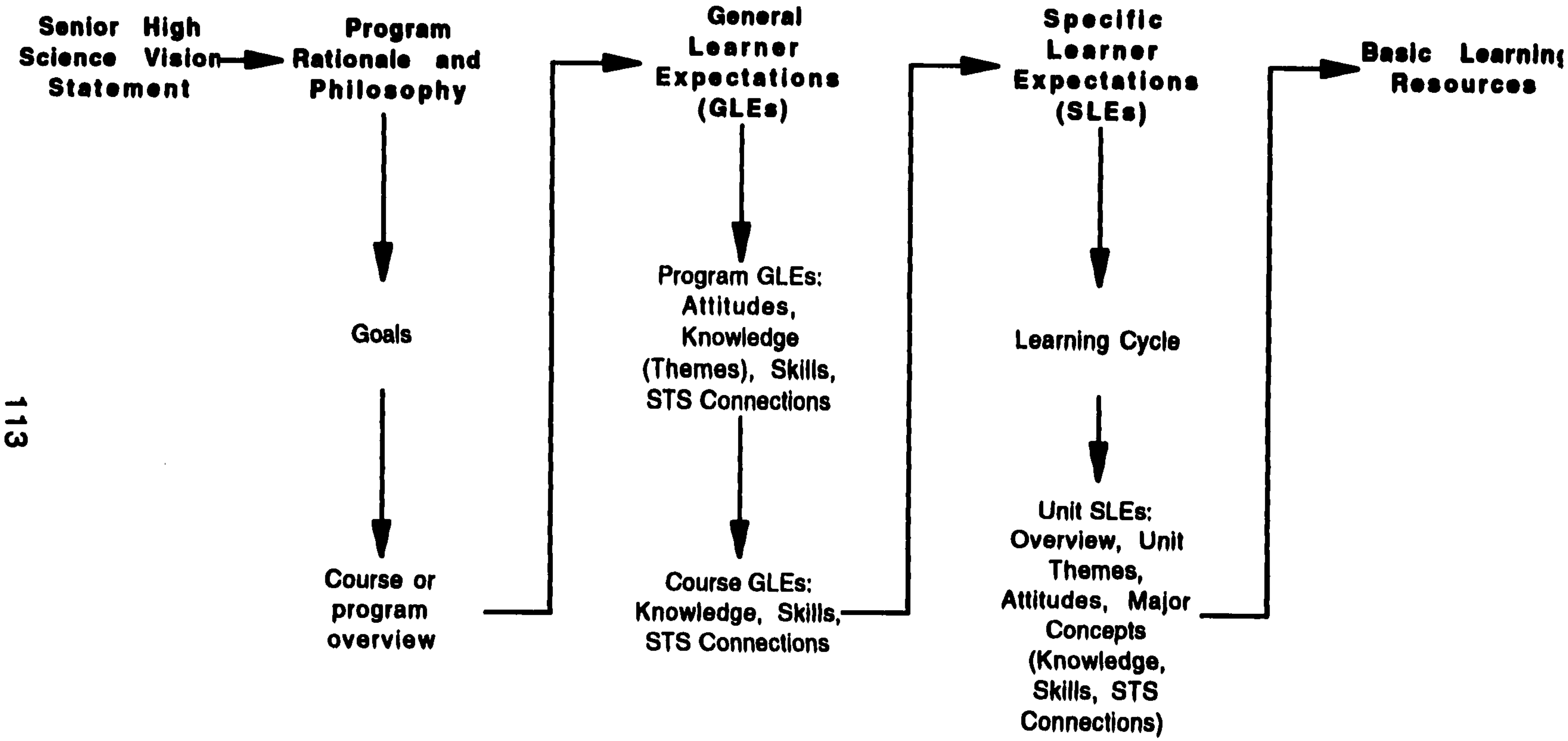

FIGURE 5.3 Common Design Framework of the Senior High Science Programs of Study

stakeholders, their parallelism emphasized their academic equality. The Program Manager commented on this issue:

H: And now the key question here is, what did you see the need for, and the advantages of, doing this?

R: The advantage first of all is for the student...if they are going to be experiencing certain skills in one subject area then they could hopefully transfer some of that to another area. To get teachers talking to one another, because suddenly they are confronted by things that are kind of similar...we wanted more dialogue and discussion. And there was another reason too. I didn't want ... different designs in comparison to the Science 10-20-30 either...whatever I could do through the curriculum, that I would try and level things off...

The preceding quote also brings up two more issues (1) transferability of skills from one subject area to another and (2) the professional development issue of increasing dialogue and discussion between teachers. The Program Manager elaborated on how the leveling of standards between courses addresses issues of articulation with post-secondary institutions.

H: ...It is an articulation problem.

R: Yes, it is an articulation problem... we were also bound and determined through this revision process to try and wherever we could to soften the boundaries between the disciplines...because we were focused on student needs and to a lesser degree we were focused on the teacher needs... So, if there was any way we could make a connection between the biology stream, the chemistry stream or with the physics stream, we would provide those points of contact for the student.

Further discussion with the Program Manager moved to a conversation about the evolution of the format of the programs of study. I commented that I thought it was interesting that one of the most recent versions (1995) of the programs of study which I downloaded from the Alberta Education Web site had the Vision Statement separated from the programs of study. In earlier versions, the Vision Statement constituted the first section of the programs of study. He noted that this was not intended but that it was probably be "an ease of access or format issue". It did bring into the discussion how these documents have evolved over time. For example, this same version (see Appendix D[1]) has also amalgamated the general learner expectations and specific learner expectations into one section called learner expectations rather than two separate sections which were found in earlier versions. The Program Manager pointed out that the "course general learner expectations for knowledge, skills and STS expectations ...were actually retrofitted" into the programs of study. By this he means they were included later to make the articulation of document more complete.

The appearance of a description of a constructivist-based learning cycle within the specific learner expectations is interesting since Alberta Education policy dictates that they do not deal with pedagogy. The learning cycle is not found in the programs of study for other levels of science education or in other subject areas. However, since there was a significant change in the nature of the science programs, the learning cycle was included as a reminder to the science teachers that the sequence of presentation of the programs of study is not the appropriate sequence for its pedagogy. The Program Manager validated this assertion in the interview:

> R: It was a huge change, we changed the structure and we changed what the program was going to be ... we had to try to provide a broader view. Do you realize that science is the only program of study that has an indication as to how you can possibly teach this stuff? It is called the learning cycle. Alberta Education policy is quite explicit. We only lay the standards out and we don't meddle in the nature of pedagogy...
>
> H: ...it is presented in a very general way. You can always argue...that it is part of the background and the rationale and the context and the content of this change...

Because of the connection between the learning cycle and pedagogy, the learning cycle is elaborated in the teacher resource manuals. It is recommended in the teacher resource manuals that the sequence of presentation of the programs of study should be read in the reverse order (from

[1] Appendix D presents the most recent (1995) versions of the programs of study which differs in minor detail from the earlier draft versions in effect at the time of program development.

right to left or STS connection to major concept) when planning instruction. The lesson exemplars in the *Science 10 TRM* (Alberta Education, 1991b), and the background, exemplars and resources also follow the learning cycle.

FIGURE 5.4a and FIGURE 5.4b present the vertical and horizontal **articulation of the Alberta senior high science programs** respectively. Clear relationships among program structure and content is important for the purposes of student decision-making when they choose their path through the various courses. Since a student can take any of a number of paths through the 20-level and 30-level courses, questions of articulation among and between the courses were scrutinized in detail by various committees when course content and sequence of topics was established and again during the field validation of the programs of study.

Articulation is an important issue in all programs in Alberta. It is important to allow students the flexibility to cross-over into different program streams should the student change career paths. For example, if a student is registered in Science 20 but decides in grade 12 that they need Chemistry 30 as a prerequisite for a post-secondary program (vertical articulation), a school could allow the student to take Chemistry 30 without Chemistry 20 as a prerequisite. This may be acceptable because major concepts in Unit 3 of Science 20 are horizontally articulated with respect to content (although not in depth of coverage) with some of the units in Chemistry 20. Appendix D presents excerpts of the Science 20-30 and Chemistry 20-30 programs of study for comparison.

FIGURE 5.4a depicts the vertical articulation between the school science programs. Science program revisions occurred first at the junior high level, with Grade 7 implementation in 1989 and Grade 8 and Grade 9 implementation in 1990. This was followed by the development of the senior high science programs and implementation of Science 10 in 1992, the 20-level courses in 1993 and the 30-level courses in 1994. Subsequently, the elementary science program has come under revision with implementation of the new elementary science program in 1996. The closest articulation occurs within the junior high level and within the senior high level. For example, Science 7, 8 and 9 were

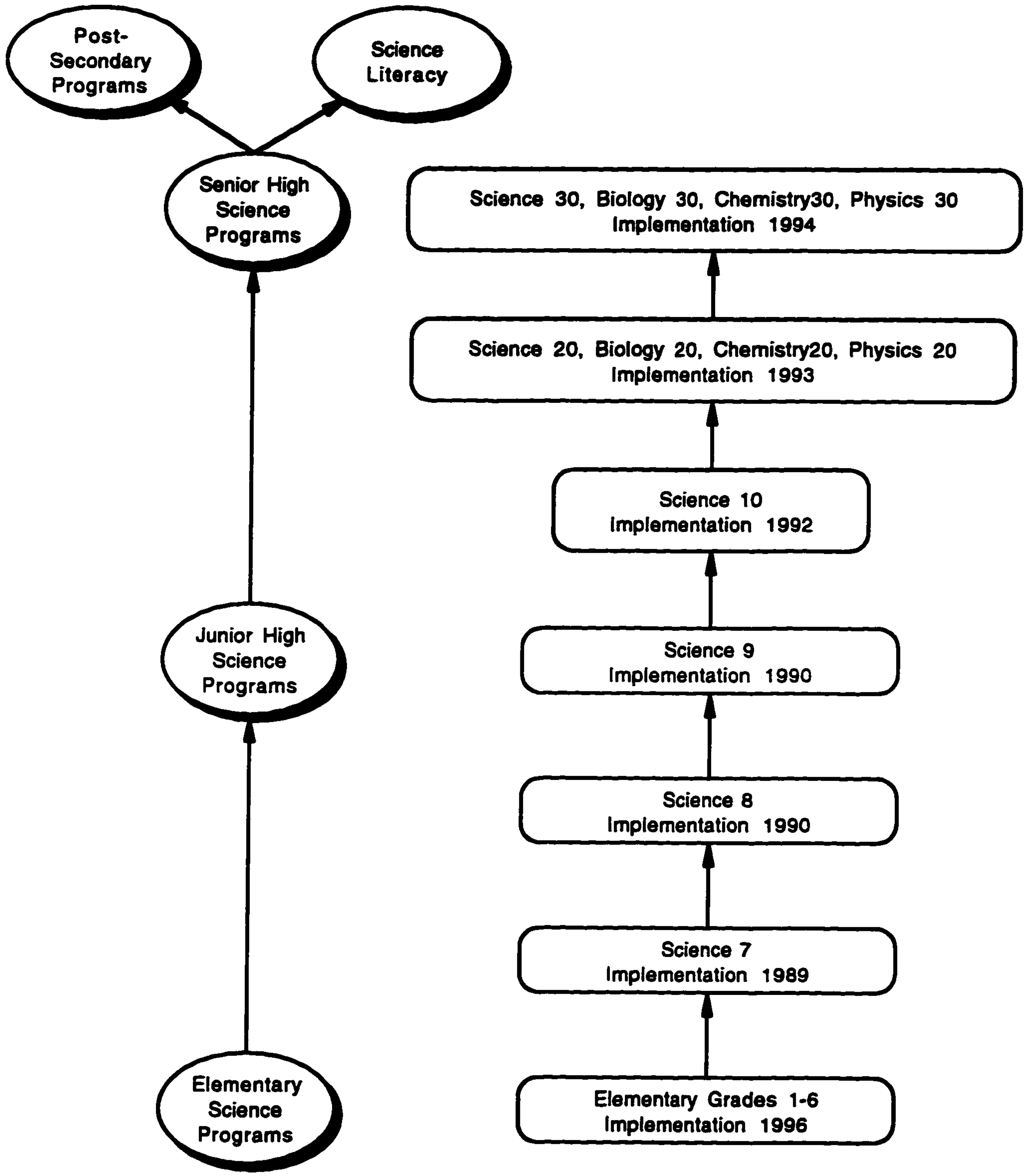

FIGURE 5.4a Vertical Articulation in the Alberta Science Programs

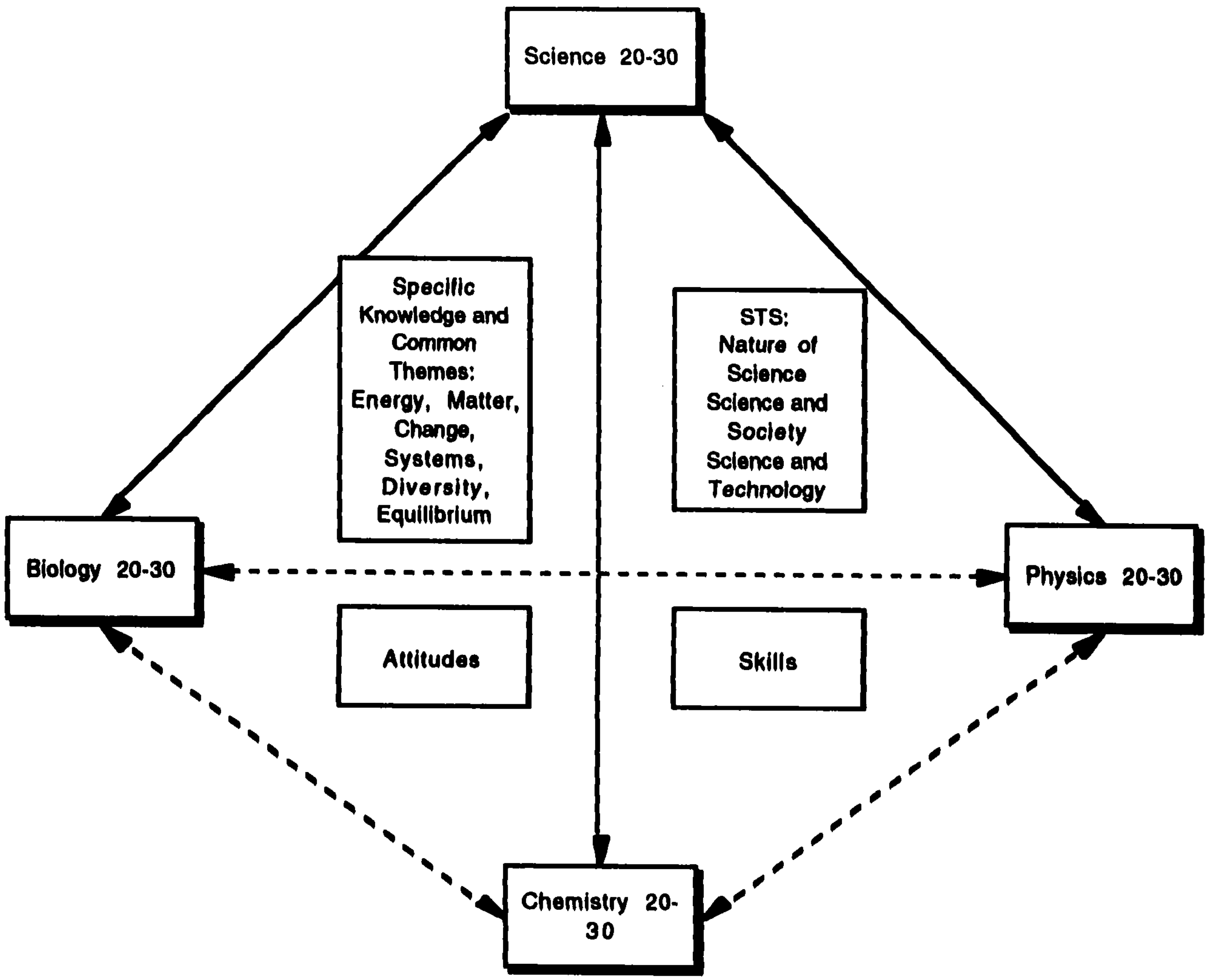

FIGURE 5.4b Horizontal Articulation within the Alberta Senior High Science Programs

developed concurrently and share a common design framework. The senior high science programs were also developed concurrently and share a common design framework. The program manager for the development of the junior high science program was not part of the Science Team. Hence, articulation between the junior and senior high science programs is perhaps not as close as it could have been if the same team of curriculum developers had been working together on all programs.

Two major goals of the science programs are to prepare students for further study and to develop scientific literacy. Articulation of the new senior high science programs with programs in post-secondary institutions was an important consideration as the post-secondary institutions determine the courses which are acceptable prerequisites for entrance into their programs. Perhaps, in retrospect, it is not surprising that the Round 2 science programs are more discipline-oriented than was the case in Round 1. Goals of scientific literacy are less tangible than specifications of topics and content, in the way this goal can influence selection of topics, skills and suggested STS connections. Since scientific literacy, however it is interpreted, is highly contextual, the matter of articulation did not seem to apply in the same way as in the specification of content and topics.

Figure 5.4b presents the pattern of horizontal articulation within the senior high science programs. Themes are integrated into all of the programs as described in the program general learner expectations. Major themes may be developed in a particular course but the subordinate themes are also present. Skills, STS connections and attitudes articulate horizontally between the 20-level courses and again between the 30-level courses. The strongest articulation occurs between the Science 20 and the 20-level discipline courses and between Science 30 and the 30-level discipline courses. There was an attempt to articulate the skills, STS connections and attitudes between the discipline courses as well.

The Program Manager was presented with FIGURE 5.4a and FIGURE 5.4b and asked to comment. The conversation turned to a set of three complex cross-articulation wall charts which were developed for the concepts, skills and STS connections respectively. The wall charts demonstrate an example of the effort that went into horizontal and vertical articulation of these aspects in the programs of study. While I have presented examples of this articulation in Chapter 4, I have not included the charts in the Appendix because of their size. The Program Manager added to the discussion of articulation as follows:

> R: If we were going to have students revisit a topic of study, we need to ask ourselves "why?" And if there are compelling reasons then we are going to deal with it in a different way...we wanted to make sure that (the topic) was also spaced out relatively well. It also provided us with audit check to make sure that we didn't have too much of one STS emphasis... in one particular area as opposed to another, to make sure there was a balance...

The Program Manager examined and deemed FIGURE 5.4a and FIGURE 5.4b as appropriate and we moved on.

Identification and Development of Resources

The identification and development of resources has a significant impact on the successful implementation of the programs. The process of identification and development of resources as well as the breadth of selection of resources, is described in Chapter 4. For the purposes of this study, I believe that the process of selecting resources is not as important as providing teachers with a broad range of resources for program implementation. By process of selection I mean the call for resources, cataloging of resources, review of resources to meet predetermined selection criteria and categorizing of resources as basic, support, other, teacher or student. The policies related to selection of resources would vary by jurisdiction so I think it would be of little significance to depict this process. The importance of the identification and development of resources lies within the selection of a wide variety of resources to support program implementation rather than the process of selection itself.

As was described earlier, selecting a wide variety of resources was a complex and time-intensive process. I spent countless hours reviewing resources and meeting with stakeholders who were interested in having existing resources reviewed or in developing resources to fit the curriculum. As outlined in the timeline in Appendix C, I also presented several sessions at inservices, conventions, conferences, and professional development days describing the resources available to support the science programs, with a particular focus on the use of technology in the classroom. The number of requests by jurisdiction for presentations related to resources is an indication of the importance that was placed on this component of program development. FIGURE 5.5 presents a schematic of the breadth of resources that were identified and developed to support the implementation of the senior high science programs. It is presented to depict a timeline of identification and development with the earliest published resources at the bottom of the schematic and the most recently published resources at the top of the schematic. The schematic also presents a continuum of resources that were developed and identified to support the science programs. On the left are the resources that were developed by Alberta Education, in the middle are the custom-developed textbooks which were developed in consultation with Alberta Education and on the right are resources identified or developed by organizations or companies external to Alberta Education. The arrows indicate the interrelationships among the resources. For example, the *Senior High Science Teacher Resource Manual* (Alberta Education, 1991a) and the *Senior High Video Series* both describe the intent and content of the new programs and describe teaching strategies supportive of the intent of the new curriculum. One of the unique characteristics of these resources was that they all supported the program directions. The Program Manager commented on this in the interview as follows:

> R: ...often when you want to make change, if you've got a system and subsystems within it and if they are pointing in the same direction, the subsystems, then if they are ready to bring about the change, your chances of change are marginally better than if you have subsystems that are pointing in every different direction.

This development of teacher resource manuals and videos was not unique to the senior high science project. Precedents were set in other curriculum development projects such as the Teacher Resource Manual for Science 14-24 and the Junior High Science Video Series. The Inservice and Implementation Consultant commented:

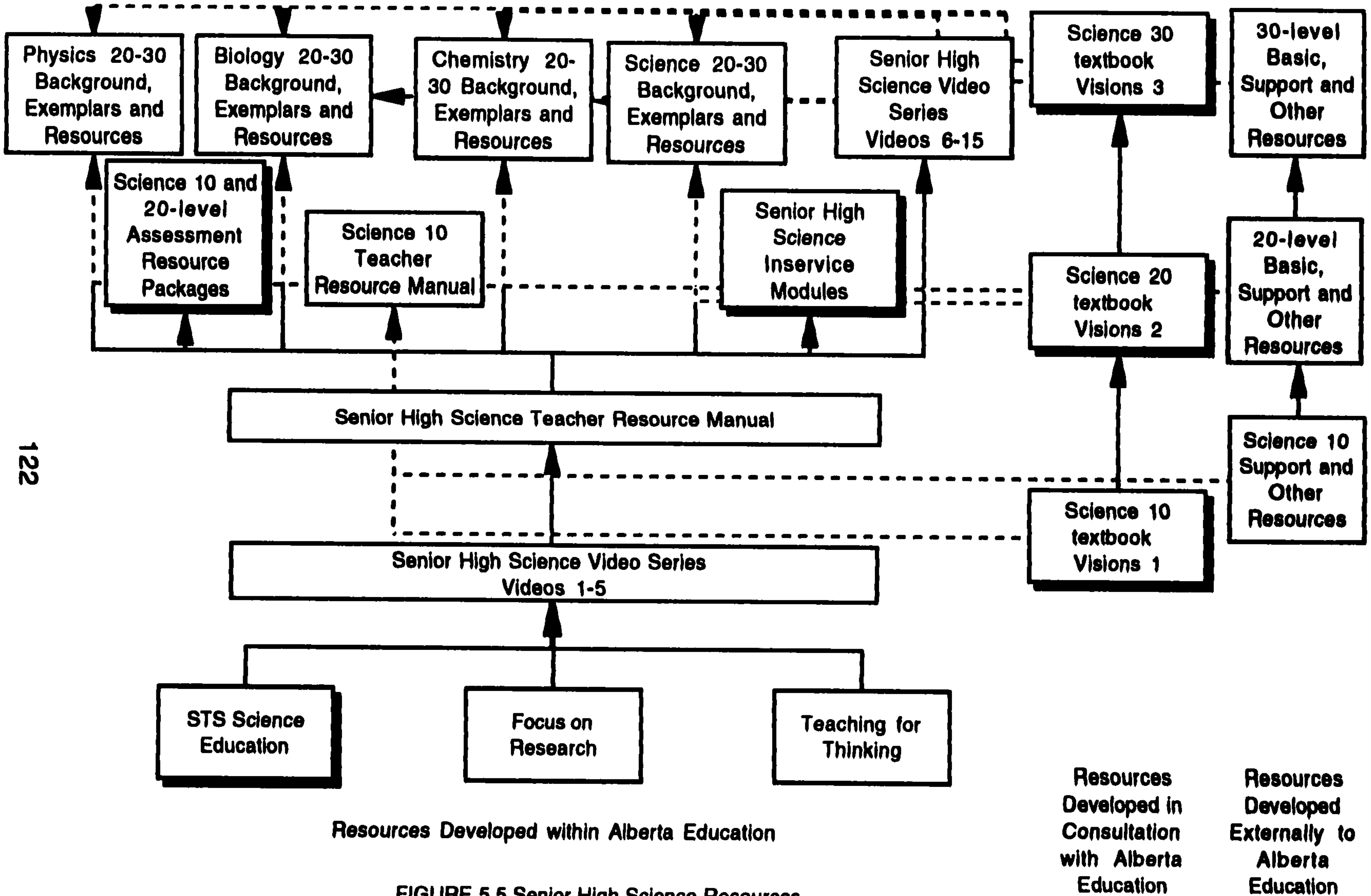

FIGURE 5.5 Senior High Science Resources

> The resource activities were not out of line with what was going on in the other curriculum development projects since the Secondary Education Review. All of the programs that came on stream did all calls, and there was a real thrust to get into technology, to review software, to make sure that there were videos that were modern... But the difference in the senior high science program was that we couldn't find a textbook in the call and so the custom development added a level of complexity to that say of the social studies program or the math program that had been introduced in the past. But there was no book and nobody anticipated coming up with a book would be and how much involvement Alberta Education would need.

However the development of the custom-published textbooks was unique to the senior high science programs. Normally an existing textbook could be found to fill the role of a basic resource. In the case of Science 10-20-30, a textbook could not be found and a custom-published textbook was contracted. The situation was further complicated by the extensive role the program consultants ended up playing in the writing and revisions of the textbooks, a role that was not intended when the contract was originally drawn up. Other unique resources included the Senior High Science Inservice Modules and the Assessment Resource Packages. The significance of the development of these resources lies in the flexibility of the curriculum development process to respond to needs identified during the consultation and communication process.

Professional Development

Professional development is important to the implementation of a curriculum development project (Romanyshyn, 1996). To bring a program to life in a classroom is a complex matter in which one learns and adapts over a period of time. There were, and still are, many opportunities for the senior high science teachers to prepare themselves for the implementation of the senior high science programs. FIGURE 5.6 presents a schematic of professional development opportunities for Alberta senior high science teachers. These opportunities include (1) attending zone meeting and information sessions (2) reading (or viewing) the support materials such as the background documents, the teacher resource manuals and the senior high science video series (3) attending relevant sessions at professional development days, conventions

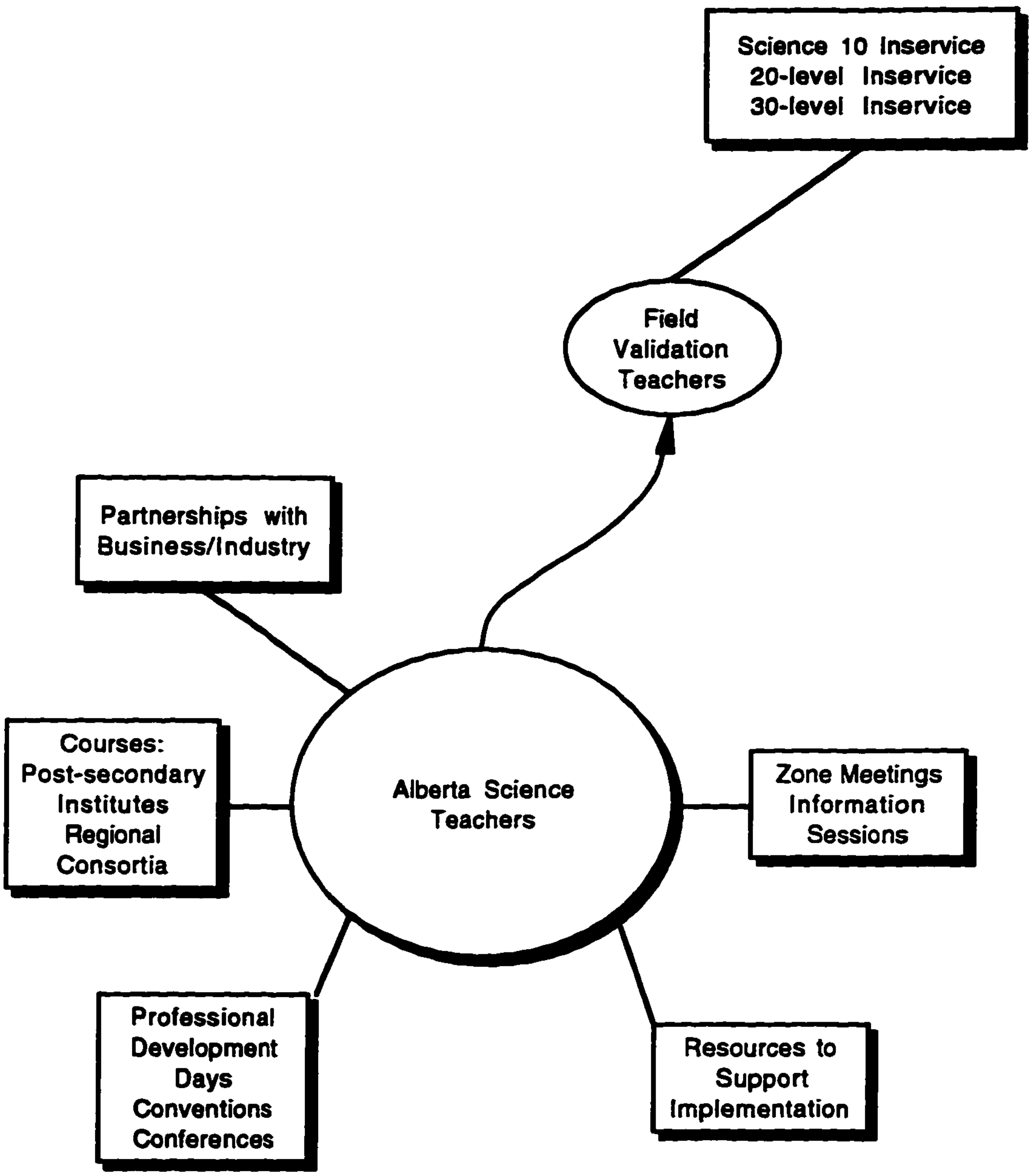

FIGURE 5.6 Professional Development Opportunities for Alberta Science Teachers

and/or the ATA Science Council Conferences, (4) taking post-secondary courses, summer institutes and/or courses offered through regional consortia or (5) participating in business/industry partnerships. While the Alberta Education presence in implementation is no longer central, various opportunities such as the ATA Science Council Conference, teacher professional development days and teacher conventions continue to exist for professional development. A special professional development opportunity for field validation teachers existed in the Science 10 inservice, the 20-level inservice and the 30-level inservice. These opportunities were described in more detail in Chapter 4 and extensively in Romanyshyn (1996).

Why was there such an extensive resource identification and professional development strategy? The interrelationship between resources and professional development is strong because of the influence these components have on the implementation of the science programs. Perhaps part of the reason for the extensive strategy was political as Alberta Education could not let the curriculum revisions falter a second time. The Inservice and Implementation Consultant agreed with my assessment:

B: ...If you were to compare the junior high science to the senior high science, I would guess that there was 20 times more resources for senior high science and that had to do with, I think, the political profile that the program had at the time.

Romanyshyn (1996) identifies some of the concerns that teachers have raised with respect to program implementation including the availability of support resources and professional development opportunities.

Consultation and Communication

Clearly, consultation and communication both within the curriculum development process and with multiple external groups, such as teachers and other stakeholder groups with political influence, is a complex and recursive process - complex because channels exist at numerous different levels and recursive because the communication goes back and forth.

FIGURE 5.7 portrays the consultation and communication process for the development of the programs of study. It should be noted that the development of the programs of study was the component which required the most extensive consultation and communication (although the components are so closely related it is difficult to separate one component from another). The process was modified slightly for the identification and selection of resources and professional development, as was described in Chapter 4. The process of consultation and communication for the development of the programs of study was further divided into internal communication and consultation (within Alberta Education) and external consultation and communication (with stakeholders in science education).

Figure 5.7a Internal Consultation and Communication describes the levels, including committees, within Alberta Education from the Minister of Education down to the Science Team. This also corresponds to the hierarchy of approval. The committees were provided with information about the development of the programs of study, the development of the teacher resource manuals, the progress of the field validation and the implementation. Opportunities for input were extensive as internal meetings occurred frequently (often weekly or biweekly). The Program Manager was presented with FIGURES 5.7, 5.7a and asked to comment. On FIGURE 5.7 and FIGURE 5.7a he commented:

R: ...That is how it works but I have to tell you that this team was pretty much given its own head to go ahead and do its job with very little interference...

and

H: Would you, in terms of fundamental validation (agree) that it is really the Science Team that is seen as the linchpin both within the internal communication and also within the external communication pattern?

R: Absolutely, the only people we reported to was that individual (the ADM) and keeping the Director informed obviously and this committee, the Ministers Advisory Committee.

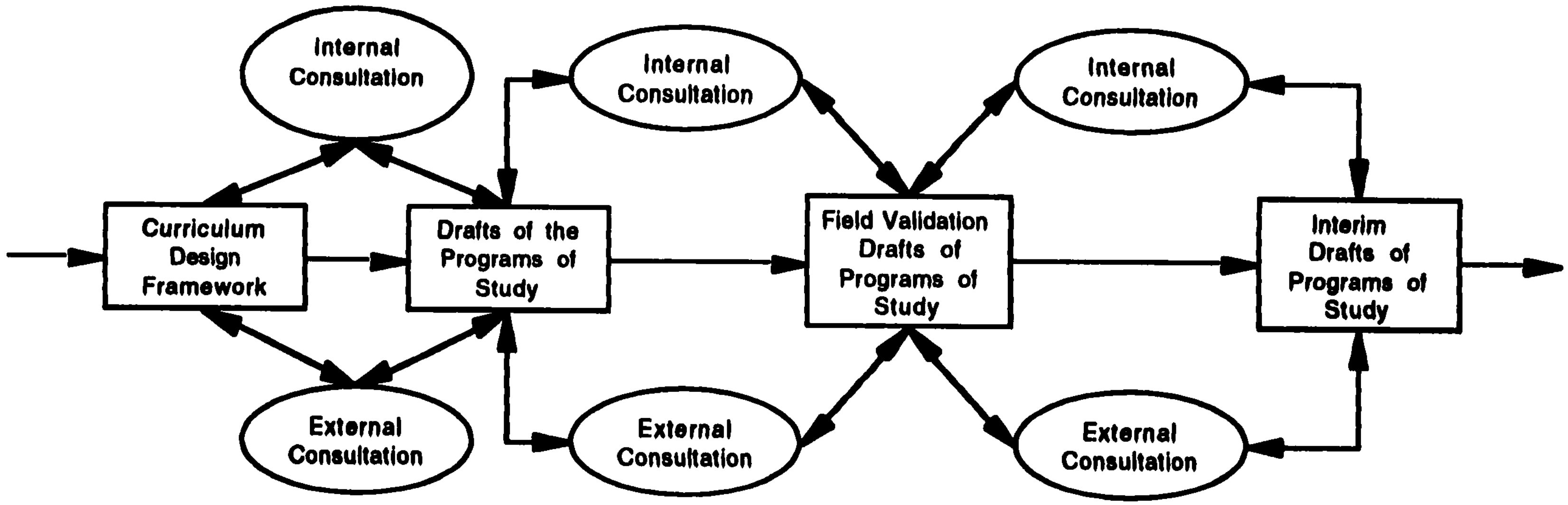

FIGURE 5.7 The Patterns of Consultation and Communication in Alberta Curriculum Development

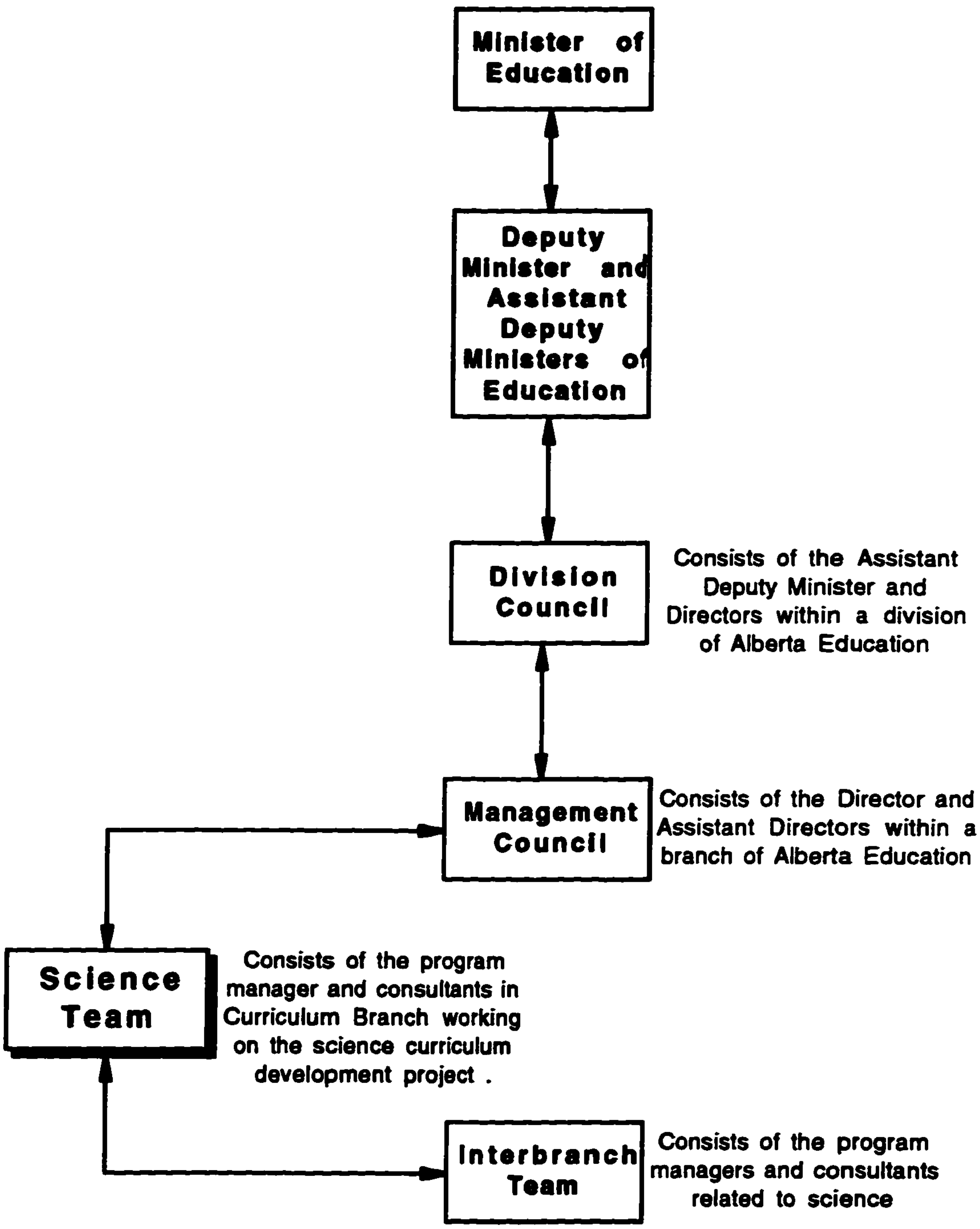

FIGURE 5.7a Internal Consultation and Communication

FIGURE 5.7b presents the external consultation and communication process. The spatial hierarchy is not intended to represent the importance or influence the particular committee or group had on the development of the programs of study. The darkness of the line connected to the Science Team represents the influence of the group. This was confirmed by the Program Manager during the interview. He ranked the strength of the influence between the external group and the Science Team, from (1) having a stronger influence and (5) having a weaker influence as follows:

1. Field validation teachers
2. Ministers Advisory committee
3. Subject area sub-committees
4. Alberta Science Teachers
4. Other science education stakeholders
5. Senior High Program Coordinating Committee.

Although he perceived the Alberta Science Teachers and the other Science Education Stakeholders as having a relatively weaker influence, he also noted their importance.

R: This by the way, we called our "trap line" (draws a connection between the Alberta Science Teachers and Other Science Education Stakeholders). That was the term that I used...

H: Why did you call them that?

R: If you had a problem, where you needed to fly something by (you know, the small p political) you'd phone some people and say "We're thinking about doing this and this and this, what do you think? You know, without having to do it on an official basis.

H: You were testing the water.

R: You got it, yes.

H: ... I think that the trap line is crucial, its absolutely crucial.

R: Its absolutely crucial and as I have said. Having that vision helped, having a team committed to that vision helped, staying on course helped and of course sometimes when you had to make changes, we made them.

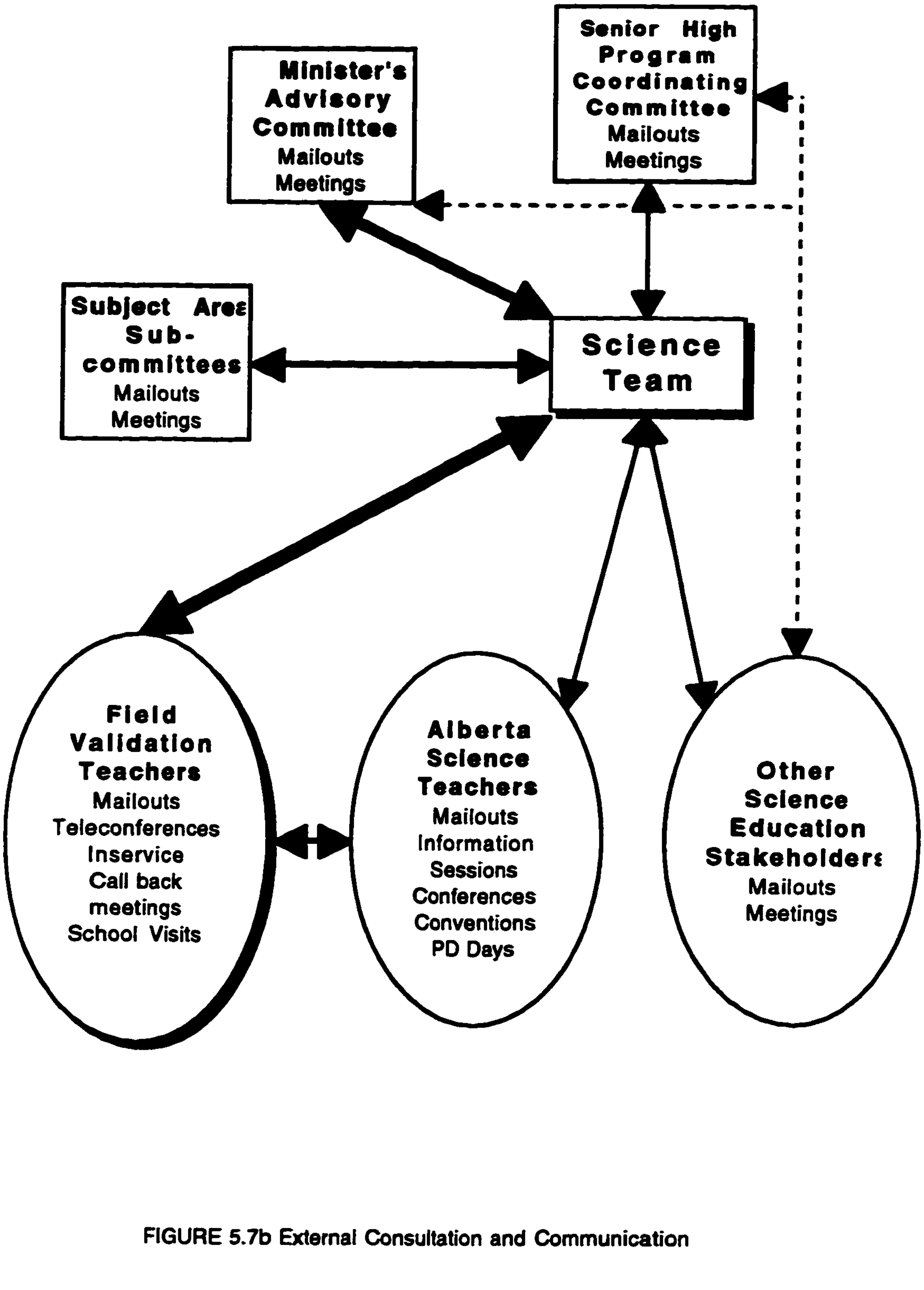

FIGURE 5.7b External Consultation and Communication

The interview with the Inservice and Implementation Consultant confirmed the importance of informal communication and consultation. She notes that communications

> B: were being funneled in all directions... to the actual process of the revisions of the curriculum, and the development of the textbooks...all their teaching colleagues...if anyone was talking to anyone at the University or any point that came up, we (the Science Team) met regularly and all of those things were shared and "Are you hearing anything like that?" so there was I think constant informal, external communication that fed into the internal.

Some of the patterns of communication are a function of the stage of program development. Although the Minister's Advisory committee and the subject area subcommittees were the first groups to be consulted at the initial stages of the development process, the other groups were consulted frequently throughout the development process as well. Early in the development process, the groups were given frequent opportunities for input mainly through meetings and mailouts of programs of study and response guides. Later in the development process the consultation process became more of a process of communication as opportunities for significant change became fewer. For example, once the custom-developed textbooks and teacher resource manuals were published, the specific learner expectations were only revised for the purposes of clarification or they were deleted for the obvious reason that the resources would not be revised to reflect minor changes to the programs of study. The exception to this shift from consultation to communication was feedback from field validation teachers. Although all stakeholder groups were consulted, the greatest influence on changes to the programs of study came from the field validation teachers as these were the teachers who taught the course during the field validation years. As the field validation continued, in 1992 and 1993, the teachers became more familiar with the entire program and were better able to comment on inconsistencies in the programs of study, lack of articulation of topics or to make other suggestions for improvement. This was one advantage to the staggered dates of implementation for each of the levels of courses.

There was also interaction between the internal and external consultation through the Science Team. As noted in the interview with the Inservice and Implementation Consultant:

> B: I guess I saw a lot of interaction between the external and the internal that was ongoing throughout because there was so much consultation going on the external feedback, and the external informal communication that was going on, every member of the Science Team was constantly feeding that back to the process, and then that would be fed into internal consultation because it would result in changes to the program...

This quote reaffirms the recursive nature of the consultation and communication process.

The consultation and communication process was modified slightly for stakeholder input into the identification and development of resources and professional development. For example, the identification and selection of the resources was done by two main groups: a resource symposium in which stakeholders were asked to select basic resources for the 20-30 level courses and the Science Team. Although other groups were actively encouraged to recommend resources for review, those participating in the resource symposium and the Science Team were responsible for the selection of resources. In the area of professional development, the committees and field validation teachers were consulted regarding the inservice needs of the field validation teachers through meetings, teleconferences, and inservice journals. The committees and science teachers (both field validation and non-field validation teachers) would be consulted regarding their needs for information sessions, conferences, conventions and professional development days. Most of these sessions were presented at the request of the convention association or jurisdiction.

The sequence of schematics presented here portray some of the interrelationships between the major components that are considered important in the curriculum development process. The set represents one way of focusing attention on various aspects of the process. The process, I believe, is complex, recursive and holistic.

CHAPTER 6 - SUMMARY, DISCUSSION AND IMPLICATIONS

Study Summary

This case study is a descriptive and interpretive study of the development of the current academic Alberta senior high science programs. In Chapter 2, the review of the curriculum literature, I discussed definitions of curriculum and aspects of curriculum theory such as perspectives of curriculum and curriculum ideology. I discussed some practical or procedural aspects of curriculum such as organization of curriculum and models of curriculum development. Finally, I discussed aspects of managing curriculum change.

In Chapter 3, I discussed global reforms in science education, specifically STS curriculum projects and Canadian context for curriculum development. I outlined some of the significant studies and literature which impacted the Alberta senior high science program directions, specifically, *Science Education in Canada* (Connelly, Crocker & Kass, 1985), *Report 36 Science for Every Student - Educating Canadians for Tomorrow's World* (Science Council of Canada, 1984) and *Science for All Americans* (AAAS, 1989).

In Chapter 4, I described the development of the Alberta senior high science programs, specifically the characteristics of the curriculum development process, the interrelationships of the components of the curriculum development process and the patterns of communication and consultation involved in the curriculum development process.

In Chapter 5, I presented a model and set of embedded sub-models to portray the Alberta senior high science curriculum development process. These models were examined by two Science Team members, the Senior High Science Program Manager and an Inservice and Implementation Consultant and were considered to be appropriate representations of the components of the curriculum development process.

Guiding Questions

Question 1 - What are the characteristics of curriculum development in a complex, multidimensional, dynamic environment?

My analysis revealed that the curriculum development process in today's educational, social and political environment is a complex, recursive and holistic process. One characteristic of curriculum development in a complex, multidimensional environment is that there are numerous interacting components. Some of these aspects are fixed such as organizational and administrative structures, while others, notably patterns of consultation and communication, are evolving. One of the components that emerged as central in importance was consultation and communication. From the events that had taken place to this point, I decided to group the rest of the curriculum development activities into three major components: (1) the development of the programs of study, (2) the identification and development of resources, and (3) professional development. Each of these components was discussed in detail to answer my first sub-question:

Question 1.1 - What are the interrelationships between program components?

The development of the programs of study appears to consist of three aspects (1) the program development considerations (2) the common design framework of the science programs and (3) the horizontal and vertical articulation among and between the programs of study. All of the program development considerations influenced the Alberta senior high science programs. However, some of these considerations had a stronger influence than others. The common design framework was significant because it facilitated the perception of equality among and between the programs and it provided a means to articulate concept, skill, attitude and STS expectations among and between the programs.

The significance of the identification and development of resources was two-fold. First, all of the resources supported the program directions, and second, the process was flexible enough to respond to the needs identified during the consultation and communication process. The availability of a wide variety of resources was key to implementation support. An important aspect of the implementation support is that the resources and professional development must be consistent with the program directions. In order for this to happen effectively, a team must share and be committed to the program direction.

Question 1.2 - How do the pattern of communication and consultation influence the shape of a complex, multidimensional, dynamic curriculum development model?

The patterns of both internal and external consultation and communication were found to be central to the curriculum development process. As exemplified by the faltering of the first round of curriculum revision, patterns of consultation and communication can provide a major obstruction if they are not used effectively. Developing support for the program change from the outset emerged as an important aspect of the consultation and communication process. It is also important to have the flexibility to respond to feedback which is consistent with the program directions. Because of this responsiveness the consultation and communication process necessarily becomes recursive. The complex and recursive patterns of consultation and communication allowed stakeholders to see that their input was valued and incorporated into all aspects of program development. While the stakeholder groups were numerous and at times, vocal, one group most affected by the curriculum change, namely the students, was not explicitly present. The discourse of the Alberta Education curriculum development process and hence the models which I have presented to portray the process did not include an explicit student voice. It was assumed by the Science Team that the voice of students would, in some sense, be heard through the field validation teachers. As is the case with curriculum development models in general, there was no direct approach taken to document the student voice. Perhaps such an action needs to be considered in future curriculum development projects.

People bring their own personal meaning to language. One of the important aspects of the senior high science program development was outlining a common language by which Alberta Education could communicate effectively with stakeholders. This called for extensive distribution of documents, meetings and informal information exchange and clarification. Crucial in the implementation phase, a wide variety of resources, feedback opportunities and workshops served to establish a shared operational set of understandings about what the various program statements meant.

Discussion

The curriculum development model described in Chapter 5 reflects certain features or ideas from preceding curriculum development models discussed in Chapter 2 but with some significant changes. In a very real sense the Alberta senior high science curriculum development process was eclectic. Taba proposed a linear model. My model is recursive. Goodlad introduced the concept of levels of organization. My model has several levels of organization. Although Schwab recognized the importance of deliberation, it was not until the large-scale curriculum development projects of the 1990s, such as the Alberta senior high science curriculum development project, that the centrality of the consultation and communication process was emphasized in all aspects of curriculum development. Walker's model described the platform of curriculum as "the system of beliefs and values that the curriculum developer brings to his task and ... guides the development of the curriculum". For the development of the senior high science programs the vision statement provided the platform for future program directions. Aoki brings two significant aspects to the process of curriculum development. First, it is a holistic model. It acknowledges that the components cannot be separated. Second, it acknowledges the principle of multiple perspectives. The Alberta senior high science curriculum development process should be viewed as a holistic process occurring in a multicultural social and political context.

Two significant aspects of the curriculum development process have been discovered in this study. The first aspect is that curriculum development is dynamic. The process must be flexible and responsive to feedback from stakeholders. The second aspect is that the curriculum development process is recursive. As the curriculum development process evolved, stakeholders were consulted with new developments.

As described earlier in Chapter 2, Fullan (1989) discusses factors related to successful change. Perhaps the successful implementation of the Alberta senior high science programs relates to some of the factors discussed by Fullan. For example, during Alberta's initiation phase (following the Minister's announcement in January 1990) each of the requirements discussed by Fullan was met. First, the educational need was linked to a high-profile political need. Following the media attention given to Round 1 of the development process, the development of the senior high science programs was certainly high profile. The second requirement (a clear model should exist for the proposed change) was also met as the vision statement clearly outlined the direction for program change. Fullan's third requirement was also met as the Science Team consolidated their resolve and their commitment to change. The fourth requirement (early active initiation establishing commitment) was also met as the Science Team consulted extensively with stakeholders in science education garnering support for the vision statement.

The implementation phase of managing change described by Fullan was also met as the Science Team carefully orchestrated the implementation plan. The Science Team provided the necessary support for field validation teachers and to some extent for all Alberta science teachers. Pressure to change was also offered by the Student Evaluation Branch through diploma examinations which clearly reflected program directions in the types of questions which appeared on the tests.

Implications

In a general sense, I am trying to suggest that the model represents features or components that a curriculum developer should consider while recognizing that it is not possible to depict every detail of the curriculum development process. Each context for curriculum development will run into its own problems which will result in amending and reshaping the model.

Models can help us to conceptualize a process by showing certain principles and procedures (Oliva, 1992). As is the case with the models described in Chapter 2, my model shows components not people. It has not attempted to relate human interaction beyond the consultation and communication process. The model is inevitably incomplete. It cannot show every detail and every nuance of a process as complex as curriculum development.

What are the implications for curriculum theory or curriculum design? Clearly the social and political context for curriculum development has changed since the introduction of the models described in Chapter 2. Curriculum development now occurs in a complex, dynamic, multidimensional environment where numerous stakeholders expect to have a say in what happens in the curriculum. Science education is becoming global as jurisdictions move toward national curricula. Yet, on the other hand there is a movement toward the inclusion of more local contexts. These seemingly conflicting movements must be reconciled in the curriculum development process. The Alberta senior high science curriculum development project occurred in one political jurisdiction. A movement to a common curriculum for many jurisdictions with different political agendas will make the curriculum development process even more complex, multidimensional and dynamic.

One significance of this study lies with other countries or jurisdictions in a similar context such as those who face large-scale centralized curriculum development projects. It may be the case that regions with a greater degree of curricular freedom would find some of the discussion in this study irrelevant to their situation. Nevertheless, questions of what constitutes scientific literacy become in a sense global as we move to a global post-industrial economy.

Questions for further research

This study is a portrayal of the Alberta senior high science curriculum development process which occurred in a particular time frame and social and political context. As such it raises some questions and issues for further research including:

1. The Pan-Canadian Science project, is developing a set of commonly shared outcomes for use in future curriculum development projects in the provinces. What impact will this kind of project involving multiple political jurisdictions have on the curriculum development process and the models portraying the process?

2. How has the Alberta Senior High Science curriculum development project influenced curriculum development in other subject areas?

3. Has the unprecedented degree of consultation with stakeholders, especially with teachers, during this curriculum development been enough from the teachers' perspective? What is an appropriate amount of consultation if the impetus for change is from Alberta Education and stakeholders other than teachers?

4. It has been said that Alberta has a group of science teachers who have a very good understanding about curriculum and that this understanding results in thoughtful responses during the consultation process (interview with science program manager). What does having a good understanding of curriculum mean? What can be done to ensure that teachers have a good understanding of curriculum? What influence does this have on the curriculum development process and the implementation of a curriculum change?

5. The Science 20-30 programs was intended for the majority of students? What kinds of official initiatives would increase the numbers of students taking Science 30?

6. The senior high science programs of study in Alberta were designed to horizontally articulate skill, attitudinal and STS expectations. Do students make the transfer from one subject area to another ? Do students transfer skills between units in Science 20-30?

7. Analysis of the consultation and communication process indicated a lack of explicit student voice in the curriculum development process. Future studies need to examine student interpretation of curriculum and include such views among stakeholder groups. How do students view the curriculum give that they do not have input into the curriculum?

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LIST OF APPENDICES

Appendix A

SCIENCE TEAM MEMBERS

Senior High Science Program Manager - started as Program Manager in July 1988 and is currently continuing in this position - seconded to Student Evaluation Branch in 1986 - 1988 from County of Smoky Lake # 13 to work as a test development specialist (project position). Moved to Curriculum Standards Branch to become Program Manager (project position).

Science 10-20-30 Program Consultant - seconded from Edmonton Public Schools, August 1990 - June 1992. Returned to a high school science department head position and taught Science 10-20-30 and Chemistry 20-30

Biology 20-30 Program Consultant 1 - Seconded from the University of Alberta Faculty of Science, May 1990 - September 1992. Returned to conducting research and teaching in biological sciences at the university.

Biology 20-30 Program Consultant 2 - Seconded from City of Leduc #297, August 1991 - July 1993. Returned to teaching and taught Science 10-20-30 and Biology 20-30. President of the Alberta Teachers Association Science Council (1995-96)

Chemistry 20-30 Program Consultant - contracted September 1988 - continues as a senior high science program consultant. Graduate Student, University of Alberta, Faculty of Education, 1992-96

Physics 20-30 Program Consultant - seconded from Edmonton Public Schools August 1990 - June 1992. Returned to teaching and taught Science 10-20-30 and Physics 20-30. Currently seconded to coordiniate production of videos to support the new senior high science programs.

Inservice, Implementation and Resources Consultant - contracted (date) continues as a consultant. Graduate Student, University of Alberta, Faculty of Education, 1992-96

Inservice, Implementation and Resources Consultant (project assistant)- seconded from Sturgeon School Division (February 1991-1992). Returned to Sturgeon School Division as science department head and taught Science 10-20, Chemistry 20-30 and Biology 20-30. Graduate Student, University of Alberta, Faculty of Education 1992-96.

Science 30 Diploma Exam Manager - seconded September 1992 from the County of Strathcona and currently continuing in this position.

Appendix B

Alberta
EDUCATION

Devonian Building, West Tower
11160 Jasper Avenue
Edmonton, Alberta
Canada T5K 0L2

Phone: 427-2939
FAX: 422-5129

October 31, 1994

Ms. Desiree Hackman
Centre for Mathematics, Science, and
Technology Education
Department of Secondary Education
Faculty of Education
341 Education South
University of Alberta
Edmonton AB T6G 2G5

Dear Desiree:

As a follow-up to your letter to Lloyd Symyrozum and our brief conversation the other day, we would be pleased to assist you in your Master's thesis research.

You are welcome to make arrangements with Raja Panwar for on-site use of information from the senior high science project. Any plan to archive or destroy material gathered or created during the project will be delayed until closer to our moving date so that you can access it at the Edwards Building. At present there are one or two vacant offices in the science area which you are free to use when you are at the Edwards Building.

References to individuals should be to positions or titles in the case of department staff or contractors, and to the representatives of associations or agencies in the case of committee members.

Good luck in your studies. We look forward to seeing you back in the Edwards Building.

Sincerely,

Merv Thornton
Assistant Director
Curriculum Standards Branch

cc. L. Symyrozum
R. Panwar

Appendix C

APPENDIX C CURRICULUM DEVELOPMENT TIMELINE

1984	The Science Council of Canada published *Report 36, Science for Every Student.*
1984	Alberta Government White Paper, *Proposals for an Industrial and Science Strategy for Albertans - 1985-1990*, published.
1984	Two educators from the University of Lethbridge, Alberta, proposed the best vehicle for STS science education would be a "unified science approach for grades 7 to 10" with "specialization in the traditional physics, chemistry and biology content areas restricted to grades 11 and 12" (Butt and Mokosch, 1984, p.37). In their paper the professors recommend Alberta Education develop a "separate science program route" (p. 37) for the academically capable but non-science oriented students"(p. 37).
1984-85	*The Secondary Education Review* In September 1984, the Premier of Alberta announced a review of secondary education in the province. The Alberta government reviewed junior and senior high school programs to determine the nature ofr curriculum reform most appropriate to prepare students for life in a arapidly changing society. Through questionaires, polls, invitations for contributions and contributed papers, an advisory committee gathered suggestions and advice from the public. The review discovered "no agreement on any one particular science" (Government of Alberta, 1985, p.8) among the people of Alberta. With no consensus about the directions of the new science programs, Alberta Education assumed these decisions..
1985	Alberta Science Education Consultants Council (a loose organization of representatives from universities and professional groups in Alberta interested in the content and organization of high school science education) recommended renewing high school science towards an STS approach and reorganizing high school science to include a general Science 10-20-30 stream to the Ministers Advisory Committee of the Secondary Education Review Blades, 1994, p.51).

June 1985	The *Secondary Education in Alberta* Policy Statement mandated a change in secondary school curricula. A central focus of the policy statement was the students need for a strong scientific and technological foundation for the future. The policy announced a three course sequence of General Science courses for high school and changes to the high school diploma. Senior high school students who wanted to obtain a general high school diploma would complete a minimum of two science courses and senior high students who wanted to obtain an Advanced High School Diploma would complete at least one of the following Grade 12 science courses: Biology, Chemistry, Physics or General Science
August 1985	In August 1985, work was started on developing a framework to assist curriculum developers and classroom teachers by depicting students' growth in cognitive, affective and physical domains. The monographs were published in 1987 and 1988 and were titled: *Student's Thinking, Developmental Framework: Cognitive Domain, Student's Interactions, Developmental Framework: The Social Sphere, Student's Physical Growth, Developmental Framework: Physical Dimension*
September 1985	Work began to identify the essential concepts, skills and attitudes for students to acquire before they finish grade 12.
1985-86	The Instructional Program Review. From November 1985 to April 1986, Alberta Education reviewed all core programs, including science, to see how well they matched the directions of the secondary education policy.
January 1986	Secondary Education Action Plan. A plan was released for putting the secondary education policy into practice. It described instructional program developments (including general initiatives, programs and courses, and instructional program requirements), the process for designing instructional programs (including the set up of Implementation Advisory committees, program coordinating committees, and Ad Hoc committees) and implementation of instructional programs (including partnership opportunities, professional development plans).

May 1986 — The Senior High Curriculum Coordinating Committee was established to ensure that programs were consistent with policy statements and follow a logical sequence across and within subject areas

September,1986 — First Program Manager for Senior High Science Appointed

October 1986 — *Proposal for Change in Senior High Science* This internal document included sections entitled: the Rationale for Change, Current Status, Trends in Science Education, Proposal for Secondary Science, Program Development Considerations and Implications. The Program Development Considerations were discussed further under the sections entitled: Developmental/Cognitive, Required/Elective Balance, Critical Thinking, Essential Knowledge, Skills and Attitudes, Articulation with Junior High Science, Articulation with Post-secondary, Program Transferability, Relation of Science 10-20-30 to Specific Disciplines. Implications were discussed relative to: Program Acceptance, Consultation and Liaison, Development Timelines, Learning Resources, Inservice Strategy, Budget and Equipment and Provincial Assessment.

In Round 1, implementation for Science 10 was scheduled for September 1990 to be followed by the 20-level sciences in September 1991 and the 30-level sciences in September 1992

1987

January 7,1987 Request for approval for the establishment of the Science 10-20-30 curriculum subcommittee sent to the Assistant Deputy Minister

February 2,1987 Draft of Frameworks for the Nature of Science, Process Skills, Technology, Science, Technology and Society. This was used by the program manager as background for the committees.

February 3-4, 1987 Science 10-20-30 subcommittee meeting. This meeting provided an update of the development to date, the background that members of the committee would need for the project and an outline of the tasks of the committee. The tasks included: selecting content statements, curriculum specifications, and criteria for resource selection, selecting initial learning resources for field testing, and developing curriculum guides and other related documents (Alberta Education 1987a, p.1)

March 3-4, 1987 Science 10-20-30 subcommittee meeting. The scope and sequence were clarified and expanded. The committee discussed the expansion and form of the topic development that should occur in the Program of Studies and the curricular documents. They also decided that Science 10-20-30 must integrate with the Junior High Science Program and Science 30 must be accepted by the universities. Science 10-20-30 would be 5 credits each. Earth Sciences, Chemistry, Physics and Biology concepts were to be integrated into the program but were not to be topics in their own right. The concepts were to be developed in a manner to ensure sequencing and the development of prerequisite skills (Alberta Education, 1987b).

March-May, 1987 Initial meetings of the chemistry, biology and physics (March 18-19) subcommittees were held to explain the redirection of the science programs and to establish the knowledge foundations that will be considered basic to each of the science disciplines

Senior High Science Advisory Committee meeting. The working draft of the program's goals and objectives was reviewed and the current scope documents for their correspondence to the goals and objectives.

March, 1987 *Students' Thinking Developmental Framework: Cognitive Domain*

May, 1987 Science 10-20-30 subcommittee meeting. Topics that would appear in the 1988 Interim Draft of Science 10-20-30 were chosen. Since General Science 10 was to replace studies in Biology, Chemistry, and Physics at the 10 level, some committee members felt General Science 10 should introduce these science disciplines, however the Program Manager was able to successfully argue for an integrated, STS approcah to Science 10, 20, 30. (Alberta Education, 1987c, p.3)

May, 1987 The*Essential Concepts, Skills and Attitudes* catalog was designed to assist curriculum developers in reviewing curricula to ensure that essentials within subject areas were included during revisions and to promote the integration of essential learning components across subject areas. An STS emphasis in the development of all high school science programs became policy in this document. The committee which developed this catalog had representatives from the Alberta Teachers Association, the Alberta School Trustees Association, the Association of School Superintendents, Alberta Federation of Home and School Associations, Alberta Chamber of Commerce , universities and colleges (Alberta Education , 1987d).

June 24-25, 1987 Physics sub-committee meeting discussed emphasis of essential concepts, skills and attitudes and scope and sequence outline.

June, 1987 *Proposed Directions for Senior High School Science Programs and Graduation Requirements.*This paper noted the changes to be made to senior high school programs in keeping with the secondary education policy. It then presented proposals for the content of programs, course sequences, credits for each course, and the timelines for introducing new and revised programs in schools. It proposed a general science course for all Grade 10 students, and the Science 20-30 program as an alternative to biology, chemistry and physics. The paper also suggested that the credits for Biology 20, Chemistry 20, and Physics 20 be increased from three to five (Alberta Education, 1987e).

September, 1987 First draft of Science 10-20-30 Program of Studies

September 16-17,1987 Science 10-20-30 subcommittee meeting

October 15, 1987 A package was sent to all senior high school principals, universities, educational associations, and other stakeholders requesting input into the proposed programs. The materials included: General Science Program Rationale and Philosophy Statement, Draft Program of Studies for General Science 10-20-30, a Response Guide for General Science 10-20-30. Concerns emerging in the feedback were: the breadth of scope, the format seems disjointed, too much material, anxiety about the 'textbook', funding, teacher inservice, flexibility of electives and increased compulsory credits in science (Alberta Education, 1987f).

October 23, 1987 Letter to publishers requesting submission of learning resources for consideration as a basic text for Science 10-20-30. The resources were to support the following fundamental concepts: acquire a foundation of knowledge in the natural sciences, comprehend the nature of science, understand the relationship between science and technology, understand the role of science and technology in societal issues. The resources also had to meet specifications regarding format and instructional design.

December, 1987 None of the learning resources submitted by publishersmet the specifications required for consideration as a basic text for Science 10-20-30.

December, 1987 Copies of *Directions to 1990: Alberta Education's Four Year Plan, 1987-1990* were sent to School Board Chairmen, Superintendents of Schools, Private Early Childhood School Operators, and Private School Operators. This was the first year that Alberta Education prepared a formal strategic plan. The management cycle outlined in the Plan and was comprised of: strategic planning, policy, program development, operational planning and budgeting, implementing, monitoring, evaluating and auditing and communicating. The directions and specific priorities of Alberta Education were outlined in this document (Alberta Education, 1987g).

December 22, 1987 A letter was sent to publishers inviting submission of proposals for a custom-developed textbook for Science 10-20-30. The requirements included principles for programs and resource development and specifications regarding format and instructional design. The first cut checklist for proposals included: completeness of the proposal, specific requirements and weighting for the evaluation of the proposals. There were also guidelines outlining gender and science, tolerance and understanding and timelines for resource development.

1988

January, 1988 Second Draft of the Science 10-20-30 Program of Studies

January 25-26, 1988 Science 10-20-30 subcommittee meeting. The scope and sequence for the entire program was presented and specifics for each unit were presented. Each unit was to focus on one of 3 emphases: nature of science, science and technology and science, technology and society. This was done to maintain continuity and balance in the program. Content was important for putting the emphasis in proper perspective. Each concept, skill and attitude statement was to reflect the emphasis of the unit. The document which was to be given to the publishers was discussed and the committee recommended of additions to be included in the document.

February 2, 1988 Senior High Science Advisory Committee meeting. Participants were updated on the development of the scope and sequence for Science 10-20-30, and informed that the call for custom developed resources to publishers had been issued.

February 9, 1988 Alberta Education organized a publishers liaison meeting to explain the procedures and expectations to assist publishers in the development of proposals for custom text development for Science 10-20-30.

February 15-16, 1988 Physics subcommittee meeting. The committee discussed the possibility of using a modified version of an existing resource as the basic resource, the credit reduction from 5 to 3 and the topics to be included in Physics 20-30.

February, 1988 *Update on Senior High School Programs*

March 15-16, 1988 Science 10-20-30 Subcommittee meeting

April 1, 1988 Curriculum Support Branch and Curriculum Design Branch were created by splitting the former Curriculum Branch

April 9, 1988	Receipt of proposals for custom developed textbook for Science 10-20-30.
April, 1988	Draft of Field Validation Procedure This document outlined the proposed validation activities including the purpose of field testing, a validation proposal, supervision of the field test classes and the expectations of the field test teachers.
May 2, 1988	First Cut of proposals for custom text development for Science 10-20-30.
May 5-7, 1988	Science 10-20-30 subcommittee meeting to evaluate publishers proposals. The committee narrowed the selection to four proposals. Recommendations to be tabled at the Senior High Science (SHS) Advisory Committee meeting on May 11.
May 11, 1988	Senior High Science Advisory Committee meeting. Committee members were updated on curiculum changes, textbook proposals, graduation requirements (and the reduction of credits of 20-level courses from 5 to 3), and communications. The committee saw no difficulties with the proposed changes to curricula. The committee was informed that the Science 10-20-30 subcommittee evaluated the textbook proposals and narrowed the selection to four. The Senior High Science Advisory committee further narrowed the selection to two. The committee recommended further communications with universities, technical institutes and parents.
May 13, 1988	Science10-20-30 subcommittee meeting to select one proposal for the custom developed textbooks for Science 10-20-30 .
May 19, 1988	Meeting with Legal Services regarding specifications to be included in the textbook development contract.
June 13, 1988	Approval of the textbook proposal by the Deputy Minister.
June-July, 1988	Meetings between publishers, authors and Alberta Education to outline expectations of the project.

July, 1988 New Senior High Science Program Manager appointed.

September, 1988 Third Draft of Science 10-20-30 Program of Studies.

September, 1988 Biology 20-30 Program Consultant, Chemistry 20-30 Program Consultant appointed and Science 20-30 Program Consultant were appointed. The Physics 20-30 Program development was supervised by the Senior High Science Program Manager

September 7, 1988 A new Minister of Education was appointed.

Fall, 1988 Science 10-20-30 Program of Studies and Response guides were sent to stakeholders for reaction

September, 1988 Initial inservice planning meeting between representatives of Curriculum Support Branch, Curriculum Design Branch, Student Evaluation Branch, Regional Offices of Education, Alberta Distance Learning Centre)

Fall, 1988 Preliminary *Secondary Science Implementation Plan* drafted.

October, 1988 First Draft of Physics 20-30

October 27, 1988 Science 10-20-30 subcommittee meeting

November 29, 1988 Senior High Science Advisory committee meeting. This meeting included an update on program development and inservice plans. No issues were brought up by the committee. The committee was advised of plans to mail out draft Programs of Study to teachers, superintendents, science consultants, and other stakeholders in late December or early January.

December 1, 1988 Physics 20-30subcommittee meeting. Units were reordered to reflect concerns expressed by teachers.

1989

January 1989	Second Draft of Physics 20-30 Program of Studies
January 26, 1989	A meeting of science teachers from the Edmonton area to discuss proposed changes to the senior high science programs. Expressions from this meeting and subsequent feedback through questionnaires indicates that a majority of science teachers are "opposed to a compulsory general science course and to a decrease in credits from 11 to 8 in the discipline streams" (Letter to science teachers by the Edmonton Regional Chemistry Council, March 13, 1989).
February 1989	Faculty of Science at the University of Alberta declares Science 30 unacceptable for admission to courses in their faculty.
February 16, 1989	Science Liaison Meeting (between branches of Alberta Education) included discussion of the french translation of the Programs of Study and resources, establishing equivalent formats as much as possible between the junior high and senior high programs of study, suggestions for improving the information sessions at professional development sessions and conventions and discussion of a set of 12 videos to support the new science programs.
March 16, 1989	Science Liaison Meeting included discussion of feedback on the draft STS monograph, a Senior High ACCESS video proposal and the communications plan.
Issue (9) 2 1989	An Alberta high school physics teacher writes an article in Alberta Science Teacher arguing the reduction of Physics 20 to 3 credits from 5 is a "serious threat to physics teaching in Alberta"(p.16) Concerned that physics "will not be afforded any coherent treatment in this Science 10 program" (p.17), the teacher suggests the decrease of instructional time for Physics 20 does not allow enough time for students to develop the knowledge and skills needed for Physics 30. He called on physics teachers to send a "clear, unequivocal message to those who dictate curriculum content and emphases" (p.18) that the changes proposed by Alberta Education are unacceptable in their

present form. This call was answered: scores of letters were written to Alberta Education by high school teachers expressing concern over the proposed changes to the senior high science program(Blades, 1994, p 61).

March 1989	Over 600 solicited and unsolicited submissions to Alberta Education indicated the proposed changes did not have the support of many high school science teachers. For example, the president of the ATA Science Council publicly complained in the ATA News that the new science courses disadvantage Alberta students intending post-secondary study in science (deLuna, 1989b, p.6). A high school science teacher writes an editorial in the Alberta Science Teacher describing the Science 10-20-30 program as a "Reader's Digest"science curriculum (p.2). He claims that the implementation of Science 10-20-30 leads to no less than the "death of science in Alberta" (p.2).
April 1989	Biology/Chemistry/Physics 20-30 Programs of Study and Response Guides were sent to senior high school principals, universities, and stateholders for reaction.
April 7, 1989	A report of the University of Alberta Faculty of Science adhoc committee on the proposed revision to the high school science program was sent to an Associate Director of Curriculum Design in response to a request to review the draft program of studies for Science 10-20-30. The report presented a scathing condemnation of Science 30 and stated that Scieence 10 would not be accepted as a prerequisite for courses in the Faculty.
April 13, 1989	Minister of Education announces one year delay in implementation of Science 10 (September 1990 to September 1991). The delay was to provide time for: revisions to the custom text, further teacher feedback, and communication at zone meetings to demonstrate to teachers that Science 10 is a foundation for other courses.
April 19, 1989	Biology 20-30 subcommittee meeting

April 21, 1989 Physics 20-30 subcommittee meeting discussed responses made to the second draft of the Program of Studies. Suggestions were made with regard to reorganization and deletion of content in response to the issue of time constraints.

April 21, 1989 A Science Liaison committee meeting included discussion of the one year delay in implementation of the Senior High Science program, further discussion of the communication plan, and school/business partnerships. (Agenda)

May 13, 1989 Physics 20-30subcommittee meeting. Further reorganization of the Program of Studies.

May 18, 1989 A Science Liaison Committee Meeting included further discussion of the delay of Senior High Science program implementation, further discussion of the communication plan, updates on curriculum development, Workmans Hazardous Materials Information System (WHMIS) in schools and school/business partnerships. (Agenda)

May 23-24, 1989 Science 10-20-30 Subcommittee meeting. The program of studies for Science 10 includes a greater emphasis on the chemistry of water ane the inclusion of topics from the previous Chemistry 10 program of study, such as atomic theory, and Unit 5 (Scientific Evaluation of Consumer Products) was completely redesigned to focus on topics of Newtonian physics from the previous Physics 10 program of studies.

May 25, 1989 Senior High Science Advisory Committee meeting. Participants were updated about changes to the Programs of Study: the General Learner Expectations were expanded to include skills and attitudes and a statement of required/elective components has been added. The committee was advised about the implementation delay. The Minister reaffirmed the credit allocations. The committee was also notified that the U of A response to Science 10-20-30 was very negative. The U of A's major concerns included: Science 10 would not provide the background needed for 20-level discipline courses, they wanted the reinstatement of 5 credits and Science 30 would not be accepted as a prerequisite. The committee suggested that principals and counsellors be kept better informed about program changes. There was concern over extra costs and human resources which would be required to implement the new courses.

June 6-12,1989 Zone Provincial Teacher Meetings. The meetings centered on receiving input from teachers to assist Curriculum Design Branch in modifying the Programs of Study for science, biology, chemistry and physics and suggestions for future directions were elicited. Dialogue centered on how best to resolve issues arising from the proposed programs. (6 meetings - Grande Prairie, Edmonton(2), Red Deer, Calgary, Lethbridge)

June, 1989 Biology 20-30, Chemistry 20-30 and Physics 20-30 Programs of study were distributed. Approximately 600 responses came back, mostly negative.

June 24 1989 Chemistry Sub-committee meeting

June 13, 1989 An article in the Alberta Report, Here's why Alberta should fire its Minister of Education, continues the controversy surrounding the new science programs and calls for the Government of Alberta to fire the present Minister in favour of someone willing to "consult others outside the department, not in it, to find out what kind of schools will enable Alberta to meet the competitive challenges of the 21st century" (Byfield, 1989, p.44).

June 19, 1989 An article in Alberta Report, Dumbing Down- That's What Experts Say Jim Dinning is doing to Alberta's High Schools, reports on the "growing army of critics" (p.28) to the proposed new science programs.

June 26, 1989 More articles in the Alberta Report, an Alberta Medical Association News Release, and articles in the Calgary Herald, continue to criticise the "watering down" of the science programs (Blades, 1994, pp.67-68).

July 25, 1989 The Minister of Education announces the formation of the Minister's Advisory Committee on High School Science Programs. The purpose of this committee was to provide advice of "policy and issues that affect science programs for Grades 7-12" (Ross, 1989, p. B3).

August 1989 Fourth Draft of Program of Studies for Science 10-20-30

August 1989 Third Draft of Physics 20-30 Program of Studies

August 24, 1989 Minister's Advisory Committee on High School Science Programs (Blue Ribbon Committee) established for on-going consultation on developing programs and textbook selection and development (News release) Committee had representatives of the ATA, School Jurisdictions, Post-secondary institutions, business and industry, professional organizations, parent teacher association and the public at large

August, 1989 *The Science Programs for Alberta's High School Students - A Brief Report*

September 12,1989 Science 10-20-30 subcommittee meeting. Discussion included the role of the committee, emphasis of the science program, current state of program development, review of the latest Program of Studies, and review of draft chapters of the custom text.

September 14, 1989 Physics subcommittee meeting (no minutes)

September 18, 1989 *Analysis of Program Changes for the Senior High Science Programs* prepared for presentation at meetings to show the relationship of the scientific knowledge outlined in the roposed programs to those in place.

September 25, 1989 The Deputy Minister of Education was quoted as saying that some of the controversy was the result "of flawed consultation early on in the change process" (Eamon, 1989, p.3)

September, 1989 Rhodes-Torgunrud Report *Field Study to Determine Teacher and Student Needs Regarding Curriculum Documents* and Resources - condensed report. (contract to Alberta Education)

October 11, 1989 The Senior High Science Advisory committee was updated on developments since the last meeting: the programs of study had been redrafted, the Minister committee on Science had been struck, draft copies of chapters of the Gage text had been reviewed. (The adhoc committees for the disciplines had been restructured.?) Enrollment trends in the sciences were distributed and discussed. Issues arising from various interest groups were categorized into design, structure, evaluation, implementation and content. Changes to the Programs of Studies were in response to the issues received. Discussion centered around the notion of content and program emphases.

October 12, 1989 Senior High Program Coordinating Committee Meeting. Members of the Science Team updated the committee on the developments of the new science program.

October 17, 1989 Ministers Committee on High School Science Programs meeting. Discussion of program changes.

October 1989 Biology, Chemistry, Physics, and Science subcommittees developed the initial drafts of revised programs of study. Mailout of P of S for Responses. Analysis of Responses

November 1989 *Science 10-20-30 Implementation Proposal* drafted.

November 24,1989 Ministers Committee on the High School Science Program meeting. The committee discussed science courses/credits taken by students, qualifications of secondary school science teachers, proposed course sequences /course credits, the implementation plan for senior high science programs and membership of the senior high science curriuclum committees. The committee decided to retain the structural changes to the high school program, increase the credit values of discipline courses at the 20 level to 5 credits each, and completely re-examine the content of all high school courses.

Fall 1989 Communication Plan for the New Science Curriculum

1990

January 26, 1990 Minister of Education announced a second one-year delay in implementation of all the new senior high science programs. Science 10 implementation was postponed from September 1991 to September, 1992. Changes in Programs of Study caused changes to be made in the custom developed text book for Science 10. Therefore the textbook could not be ready in time for field validation of Science 10 in September of 1990. The credits for Biology 20, Chemistry 20 and Physics 20 would increase from 3 to 5. The content of Biology 20-30, Chemistry 20-30, and Physics 20-30 would be revised so that the programs would better prepare students for post-secondary studies and careers in science. There would be increased involvement teachers, post-secondary institutions and professional groups, in the next stage of development of all the new science courses. Alberta Education would work with professional groups to provide inservice and preservice opportunities for teachers to build on their knowledge of science, and their approaches for teaching science to students (Alberta Education, 1990a).

January, 1990 Several articles are published in the Alberta Report and the Edmonton Journal praising the Minister of Education for listening and responding to public criticism.

January, 1990 The Science Team produces a tentative list of concepts and possible topics for the new senior high science programs reflecting initiatives from the AAAS Project 2061. This project proposed that science literacy is encouraged when science education is built on the major themes in science. The Science Team outlined six conceptual organizers or themes that would provide a "useful way to bring cohesion and unify scientific concepts" (Alberta Education, 1990c, p.2).

February, 1990 *Guide to Curriculum Planning in Science* (internal)

April 25,1990 Programs of Study and response guides were sent to stakeholders (high school teachers, post-secondary instructors, professional groups, scientists, government departments, crown corporations, and the private sector) for reaction. The Science Team also met with over 70 percent of all science teachers in the province (January-April). They found that teachers generally agreed with the concepts and skills in the new Science 10 Course, value knowledge as more essential than application in science education and favour keeping the current content (i.e., themes) and sequence of the new science programs (Alberta Education, 1991).

May, 1990	Biology Program Consultant appointed from the University of Alberta.
May, 1990	Provincial Zone Meetings (8 sessions held in the 6 Provincial Zones) Science team completes information and consultation sessions - implementation needs assessment done with 250 teachers, administrators and members of the science education network.
June, 1990	5th draft *Inservice and Implementation Plan* (internal) Document prepared in response to questions raised by the Minister's Advisory Committee.
July, 1990	Communications Plan sent to Assistant Director, Curriculum Branch (internal)
August 30, 1990	Ministers Advisory Committee on High School programs meeting. The meeting included discussion of the historical background and role of the committee. The Minister of Education stated the important objectives of Alberta Education: to provide more and better science for all students and to develop an enriched and challenging science program for those students interested in science related studies and careers. He stressed that consultation with stakeholders is an important part of the process for developing the new science program. The focus of the committee will be on content - with an emphasis on good, solid sicence; teacher readiness by providing inservice programs, resources, speakers lists, partnership in implementation- which inlcudes the cooperation among Alberta Education, and industry, business, post-secondary and governmental agencies. He encouraged committee members to roll back conventional thinking on science education in the development of a program which will hook kids on science and develop their flexibility, curiosity, imagination and ndependent

thinking and reasoning abilities. The meeting also included a report on consultation and survey. One problem associated with the survey was timing the distribution of the survey near the year-end when teachers and administrators were occupied with trying to ready students for exams and tie-up matters before summer. In clarifying the role of teachers in the development of curriculum, it was explained that the process used in this survey attempted to access 100% of the teachers who would be affected, whereas the ad hoc committee process utilized in previous instances involved input from only a handful of teachers. The committee was presented the *Vision of the Senior High Science Programs*. One discussion centered around enrollments in Science 20-30. Parents and counsellors have concerns about advising their children to take Science 20-30. Most enrollment decisions wil depend on requirements by post-secondary institutions. Acceptance by post-secondary institutions varies from "endorsement" to "reserved judgment". The science program will attempt to establish a compromise between two extremes: (1) Science 10-20-30 a s a mainline program aimed at sutdents with an interest in post-secondary studies while Biology, Chemistry, and Physics are maintained for those students who have decided on a career in science and (2) Biology, Chemistry and Physics as the basic science program for most students going on to post-secondary studies and Science 10-20-30 taken in concert with art/music/drama by those students who have decided on a career in an area outside of science. Ideally, Science 10-20-30 will be taken by a large number of students interested in pursuing careers requiring some sort of post-secondary education. Under the new structure of the science programs the decision on which science course to take and which post-secondary career path will be delayed from Grade 9 to Grade 10. The committee was also given an an overview of the Science 10 Course of Studies and a Sample Unit with Standards of Achievement. One point of discussion centered on the listings of STS choices. These are prescriptive but not exclusive, allowing teachers to make their own selections from those situations which may arise from their immediate environment. The committee recommended that the Science Team should explore alternatives to the presentation of knowledge, skills and attitudes in the Course of Studies as the format of the General Learmer Expectations seemed to emphasize knowledge items over process and attitudes. Discussion of the *Standards of Achievement* document centered around the evaluation of 10- and 20-level concepts and principles as they relate to the 30-level may be the subject of examination on diploma exams assuming that the curriculum truly spirals learnings from one course to another. Discussion of teacher inservice centered around Alberta Educations lack of resources to provide teacher inservice training. Therefore partnerships with various organizations are necessary to meet all the needs. Alberta Education should have a role in coordinating inservice opportunities. Discussion of the proposed outlines for the 20-30 level science programs focussed on the inclusion of specific topics suggested by committee members (Minutes of meeting).

August, 1990 *Senior High Science Draft Implementation Action Plan*

August, 1990 Physics 20-30 program consultant appointed

September, 1990 Implementation of Science 7

September 17, 1990 A package of materials was sent to superintendents and high school principals which included the Vision for Senior High Science, the draft Science 10 Course of Studies, the consultation and survey reoprt and draft program outlines for Biology, Chemistry, Physics and Science 20-30. These materials were also sent to teachers and other Albertans who completed the response guides that were distributed in the spring of 1990.

October 17, 1990 A package of materials includeing draft copies of the Science 20-30 Program of Studies, zone meeting agenda and schedule was sent to science teachers, local professional groups, network members and people from business, industry and post-secondary institutions.. The zone meetings would focus on program development and working with teachers.

October, 1990 Alberta Teachers' Association Science Council Conference (Jasper, Alberta). The program manager explains that the final version of Science 10, 20, 30 "will achieve excellence by providing a more rigourous science education. This rigour will be achieved by helping students understand basic scientific concepts, principles and laws and by the real-life applications of science and technology" (Panwar, 1991, p.8). He continued by assuring his audience that "the proposed Science 10-20-30 program is designed for academic students who want a strong foundation in science. Science 10, as a compulsory course, will give students a broader understanding of the important scientific concepts in biology, chemistry, and physics" (p. 9).

November, 1990 *Notes on Teacher Inservice Needs, Delivery Systems, Resources and Organization of Professional Development Activities - Needs identified at Zone Meetings.* (synthesis report produced by science team - internal document). *Inservice - What are the Needs?* - Science Team brainstorm based upon their experience and synthesis document (internal document). *Partnerships in Teacher Professional Development - a draft for discussion* (internal).

November, 1990 Synthesis of Responses

November 1990 Zone Meetings

November 1990 Science team tours the province - zone information meetings with discussion and recording of needs expressed by teachers - needs for implementation

November 20, 1990 Ministers Advisory Committee meeting. This meeting centered on the Science 20-30 Program of Studies. The team was commended for producing a document that would provide the direction for presenting science to students in an interesting way. In addition to increasing scientific literacy, the goal of this program should be to promote interest in science. Science 20-30 was described as a strong academic program for students entering non science faculties at university. A positive view of science and engineering careers shold be promoted in the textbook and support materials. THese are often seen as isolated, lonely careers therefore promoting negative attitudes, especially in women. The cooperative nature of careers should be communicated. The involvement of industry cabn help to provide a "truer" picture of what scientists do. The committee discussed "How specific should the program of studies be?" The major concepts should provide the general directions, while the knowledge and skill statements should provide the teacher with enough specificity to understand what is expected of the students, yet be flexible enough to allow for a variety of students' needs and interests. The textbook and Teachers' Resource Manual can provide further direction. Alberta Education plans to produce a TRM while the publishers of the text will produce a teacher's guide to complement the student textbook. The philosophical basis for discussing issues should stress balanced views, openmindedness and te multitude of perspectives. This philosophical basis should be apparent fronm the language used in all documents. The use of the terms"pros and cons" suggests there is a "wrong and right" side to issues. Students should be encouraged to view issues from a variety of perspectives. Higher level skills such as problem-solving and decision-making should be emphasized and the moral perspective and the ethics of science included. Students should be made aware of the significance of science information in the puvlic sector. Good science does not necessarily contain a lot of science facts but focuses on reliable and significant evidence. There should be consistency in the language used throughout the documents. The knowledge objectives should provide the background for the STS connections. There must, however, be a balance between the science content and the STS issues. The STS components should be embedded in the text as they are a vehicle for delivering the key concepts. There needs to be a balance of applications and issues in the STS connections. There should be a focus on lab safety, particularly WHMIS regulations, in the program. Evaluation in the diploma exam must reflect the directions of the new science programs. Science 20-30 must be carefully reviewed during the field test to ensure there is not too much content. Communication with science educators in other provinces and countries, particularly the U.S.A., was seen as beneficial in getting new ideas and insights while developing the new programs. Further discussion of the Science 20-30 Program of Studies centered on suggestions for additions, deletions or rewording of specific "content". The committee also discussed issues of professional development. Recommendations included involving the broader scientific community to help them gain a better understanding

1991

January 1991	Inservice and Implementation Consultant formally assigned responsibility for inservice and implementation support for field validation and provincial implementation - inservice plan framework was developed (January - June)
January 1991	*Science 10 Field Validation of Program of Studies and Student Text: General Information for Field Validation Teachers*
Jan. 24 1991	Executive Summary of Project Plan for Implementation of the New Science Programs (internal)
January 7, 1991	Notification of field validation sites
January 8, 1991	Biology, Chemistry and Physics 20-30 programs of study and a response guide were sent to school board members, school superintendents, high school principals and science teachers.
January 18, 1991	Science 30 Course of studies mailed to Gage
February 1991	Inservice and Implementation Consultant seconded from Sturgeon School Division
February 1991	Field Test Project - Detailed Proposal - Included draft June and August Science 10 Inservice Plans
February 1991	Invitation to Inservice Planning Meeting went to school jurisdiction representatives
February 28, 1991	Biology, Chemistry, Physics 20-30 Response Guides received from schools, teachers etc.
Feb. 22-March 8, 1991	Review of unedited Science 10 text Units 1 and 2 Committee meeting April 3, 1991

Feb. 11-March 8, 1991	Review of detailed chapter outlines for Science 20 (Science Team)
March 1, 1991	Planning Meeting on Teacher Inservice for Science 10 with school jurisdiction representatives
March 14, 1991	Revisions to Biology, Chemistry, Physics Program of Studies completed
March 14, 1991	Science Advisory Committee Meeting
March 27-April 5, 1991	Outline of Science 10 Teacher's Guide
April 1991	Curriculum Design Branch and Curriculum Support Branch collapsed back into one branch in reorganization - became the Curriculum Branch once again. The curriculum design, resources, field validation and implementation support functions were again within one branch.
April-June 1991	On-going planning for Science 10 June inservice activities for field validation teachers
April 8, 1991	Suggested Responsibility Sharing for Teacher Inservice Roles and Responsibilities sheet/overhead developed to promote collaboration
April 11, 1991	Draft Program of Studies for Biology, Chemistry, Physics 20-30 Approved
April 17, 1991	*Vision - Senior High Science Programs* & Program structure (public) *Senior High Science - Issues and Actions*
Apr. 26-May 10, 1991	Review of unedited Science 10 text Units 3 and 4 Committee meeting July 5, 1991
Apr. 29-May 10, 1991	Sample chapters of Science 20 text Committee meeting June 5, 1991

May 14, 1991	*Science 10 Field Validation Project Inservice Plan* - Science 10 only (internal) *Orientation for Science Teachers* - Plan for teachers not involved in field validation process.
May 1991	Field Validation Plan (inservice component)
May 1991	Development of the Senior High School Science, Technology and Society Programs and Resources in Alberta Report
May 1991	Appeals for funding and support assistance from business and industry for teacher inservice activities drafted - did not proceed
May 3-May 10, 1991	Sample chapters of Science 10 Teacher's Guide Science Team and teachers review July 5
May 15, 1991	Closing date for publishers to submit potential resources for the new biology, chemistry and physics programs.
May 24, 1991	A package including a summary report of responses to the draft programs, a status report for biology, chemistry and physics, Science 10 field validation and orientation information and the Senior High Science Teacher Resource Manual outline were sent to school board members, school superintendents, high school principals and science teachers.
May 16-Aug. 28, 1991	Initial Review of basic resources for Biology Chemistry and Physics 20-30
June 17-July 12, 1991	Edited Science 10 Text (Committee meeting July 5), Chapter Outlines for Science 30 text (Science Team review June 21) and unedited Teacher's Guide (science team and teachers review June 21)
June 24-26, 1991	Science 10 Inservice Program for field validation teachers (Part 1) University of Alberta, Edmonton (170 participants - 105 teachers)
July 1991	Summer Institute (Water) Presentation

August 1991	Summer Institute (Agriculture in the Classroom) Presentation
August 12, 1991	1500 manuscripts of edited Science 10 Text to Alberta. Education. 50 manuscripts of edited Science 10 Teacher's Guide to Alberta. Education.
August 15, 1991	A Proposed Model for the Assessment of Scientific Process Skills was developed by Student Evaluation Branch. It was presented at the Science 10 Inservice for field validation teachers. It included a framework for scientific problem-solving skills and criteria for assessing these skills.
Aug. 26-27 1991	Resource Symposium to select potential Basic Resources for 20 level disciplines
August 29-30, 1991	Section 2 : Science 10 Inservice Program for field validation teachers University of Alberta, Edmonton (170 participants - 105 teachers)
August 1991	Biology 20-30 Program Consultant seconded from Leduc
September 1991	Implementation of Science 8 and 9
September 3, 1991 to Dec. 20, 1991	Field Validation of Science 10 begins (semestered & full school year) 4600 Students, 95 Teachers, 29 Schools Text in manuscript format
Sept. 9-Oct. 11, 1991	Unedited first draft of Science 20 text Committee meeting Sept. 27, 1991
Sept. 1991	University of Alberta secondary education professor writes the Assistant Deputy Minister regarding research /evaluation plan
Sept. 26, 1991	Field test texts for Biology, Chemistry and Physics 20-30 approved
Oct.-Dec. 1991	School visits - 12 day-long visits to field validation schools made by science team members - classroom observations and implementation feedback

Oct.-Dec. 1991	Science 10 Teleconferences - 12 teleconferences on Science 10 (FV teachers & science team)
October 1991	The Faculty of Science at the University of Alberta approved the addition of Science 30 to the category of senior secondary school science courses, such as Biology 30, Chemistry 30 and Physics 30, graduating students may use for admission to the Faculty of Science (Faculty of Science, 1991, p.1). However, most courses in the Faculty of Science would not accept Science 30 as a prerequisite.
October 1991	Subcommittees for Biology/Chemistry/Physics to advise the Director of Curriculum on the Selection of Resources
October 4-6 1991	Science Council Conference, 2 Sessions, 70 participants 3 hour activity based workshops and Resource Booth
October 4, 1991	Review of unedited Science 10 Text
October 1991 -March 1992	Field Validation Site Visits (12 Schools)
September 30- October 25, 1991	Review of sample chapters from each of the four units for Science 30 Committee meeting Oct. 15, 1991
October 1991	Professional Development Presentations
November 1991	*Connections* newsletter developed and sent to field validation teachers *Implementation Planning Package for Senior High Science* development complete and available through Learning Resources Distributing Centre. *Senior High Science Inservice Module Package* development complete and available through Learning Resources Distributing Centre. *Senior High Science Program Teacher Resource Manual Proposal* (internal)
November 1991	Meeting with Universities (Education) re: research opportunities

November 1991	Science 10 Teleconferences
November 1991	Presentations to Post-secondary Institutions/Administrators
November 1991	Professional Development Presentations
Nov. 1991-Feb. 1992	Convention Presentations (4)
Dec. 2-20, 1991	Outline of Science 20 Teacher's Guide Science team review Dec. 6, 1991
December 1991	Science 10 Teleconferences
December 1991	Presentations to Post-secondary Institutions/Administrators

1992

January 1992	Letter to Superintendents re: Science 10 implementation support - resources, information session dates and registration information, equipment list - went to all superintendents.
January 1992	Presentations to Post-secondary Institutions/Administrators
Jan.-Mar 1992	Teleconferences - 12 teleconferences held on Science 10 (Field validation teachers & science team)
January 27, 1992	Southern Alberta call-back session for field validation teachers Calgary (Round 1 of Science 10 completed the in semestered schools)
January 30, 1992	Northern Alberta call-back session for field validation teachers Edmonton
February, 1992	*Senior High Science Program Implementation - Information and Suggestions for Administrators* (public) *Senior High Science Program Implementation - Information and Suggestions for Teachers* (public) for use with field validation schools and for information session and all other schools implementing in Sept. 1992
Feb. 14-15, 1992	Page proofs of Science 10 text and teacher's guide reviewed by the science team
Feb. 17-28, 1992	Sample chapters of science 20 teacher's guide
February 1992	*Suggestions for Teachers Implementing Science 10,* and *Senior High Science Program Implementation Information and Suggestions for Administrators* were mailed out to schools
February 1992	Professional Development Presentations

February 28, 1992	Field test texts for Biology, Chemistry, Physics 20-30 shared with field test teachers
Feb.-March 1992	Science 10 Assessment Resources Development Project
March 1992	Provincial Information Sessions - 5 full day information sessions held across the province Edmonton, Red Deer, Calgary, Grande Prairie, Lethbridge - 420 teachers attended (designed for teachers implementing Science 10 beginning Sept. 1992)
March-May 1992	20-level Assessment Resources Development Project
March 1992	6 Information Sessions across province re: Science 10 485 Participants
April 1992	Science 10 Teleconferences
April 6, 1992	*Suggestions, Questions and Comments from Teachers at Information Sessions* (internal synthesis - science team)
April-June 1992	On-going planning for 20-level June inservice activities for field validation teachers *Proposal for Inservice - 20-Level Science Courses* (internal)
May 1992	Science 10 Teleconferences
May 1, 1992	*Senior High Science Program Development and Validation Report* (public)
May 20, 1992	Science 20 Inservice program plans finalized and mailed to all field validation teachers - allowing for early selection of workshops.
May 26, 1992	The New Senior High School Science Program - Update for Science Teachers, Consultants and Administrators
May 11-June 19, 1992	Unedited first draft of Science 30 text. Committee meeting June 10, 1992

May 1992	Draft - *Strategies for Implementing the New Science Programs* (internal - evolving)
May 1992	Presentations to Post-secondary Institutions/Administrators
June 1992	Science 10 Teleconferences
June 1992	Senior High Science TRM and Science 10 TRM completed Drafts of 20 level TRM's ready for inservice
June 15-July 10, 1992	Edited version of Science 20 text. Committee meeting June 30, 1992 Unedited Science 20 Teacher's guide- reviewed by science team and teachers
June 21-25, 1992	20-Level Sciences Inservice Program for field validation teachers University of Lethbridge (170 participants - 125 teachers)
End of June , 1992	Field validation of Science 10 completed
August 24- Sept. 18, 1992	Outline of science 30 teacher's guide - reviewed by the science team
September 2 1992 to Dec. 18, 1992	Field Validation of 20-level Courses 3920 Students, 125 teachers, 30 schools Science 20 Text in manuscript format
September 1992	Provincial Implementation of Science 10. Field Validation of 20-level Sciences begins*Senior High Science Program Development and Field Validation Report* (public) - mailed to all school jurisdictions and schools
October 1992	Science Council Conference - 20 level courses 3 hour activity based workshop and resource booth
Oct.- Dec. 1992	12 Teleconferences held - major focus Science 20

November 1992	Draft Section E of Program of Studies
December 1992	*Connections 2 for Science 20 Field Validation Teachers*
December 14-	Sample chapters of Science 30 Teacher's Guide

1993

January 8, 1993	Reviewed by the science team
Jan.-Apr. 1993	9 Teleconferences held - 20-level discipline sciences major focus
Feb. 12-26, 1993	Page proofs of Science 20 text and teacher's guide reviewed by the science team
February 1993	*Meeting the Challenge* (public) - prepared for distribution at information sessions and mailouts to school jurisdictions.
March 1993	Announcement re: single high school diploma to replace 2 diploma system
March 1993	Provincial Information Sessions - 8 full day information sessions held across the province Edmonton (2), Vegreville, Red Deer, Calgary, Airdrie, Grande Prairie, Lethbridge - 700 participants (designed for teachers implementing 20-level Sciences beginning Sept. 1993)
April 1993	*Senior High Science Programs: Development and Validation Report* - 20-level sciences field validation in progress. (public)
April-June 1993	On-going planning for 30-level June inservice activities for field validation teachers
June 1993	Draft 20-30 TRM available for inservice

June 20-24, 1993 30-Level Science Inservice Program for field validation teachers University of Calgary (170 participants - 135 teachers) Field Validation package

End of June 1993 Field validation of 20-level Sciences complete

June 7-July 2, 1993 Edited version of Science 30 text. Committee meeting June 24, 1993. Unedited Science 30 teacher's guide.Reviewed by the science team and teachers

Sept. 2 1993 Field Validation of 30-level Courses

Dec. 17, 1993 3500 students, 100 teachers, 37 schools. Science 30 Text in manuscript format

September 1993 Field Validation of 30-level Sciences begins (3500 students, 125 teachers, 37 schools) Provincial Implementation of 20-Level Sciences
Senior High Science Program Development and Implementation Report - field validation of 20 -Level Sciences complete, 30-level Sciences just beginning (public)

October 1993 Science Council Conference - 30 level courses

October 1993 Educational Roundtables: Background for the 3 Year Plan

Sept.-Dec. 1993 12 Teleconferences - major focus Science 30

1994

Jan.-Mar 1994 12 Teleconferences - major focus 30-level discipline sciences

Feb. 11-12, 1994 Page proofs of Science 30 text and teacher's guide reviewed by the science team

Feb./March 1994 9 Information Sessions re: 30-level courses

March 1994	Provincial Information Sessions - 8 full day information sessions held across the province Edmonton (2), Vegreville, Red Deer, Calgary, Airdrie, Grande Prairie, Lethbridge - 800 teachers attended (designed for teachers implementing 30-level Sciences beginning Sept. 1994)
May 1994	*Planning Ahead - Post-secondary requirements*
June 1994	30-level Sciences field validation complete
September 1994	Provincial implementation of all 30-level Sciences

Appendix D

SCIENCE

VISION STATEMENT: 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. The same framework was used for the development of all the senior high science programs, including Science 10, Biology 20–30, Chemistry 20–30, Physics 20–30 and Science 20–30. The expected student knowledge, skills and attitudes are approached from a common philosophical position in each science course.

In the senior high science programs, students focus on learning the big interconnecting ideas and principles. These ideas, or major themes, originate from science knowledge that transcends and unifies the natural science disciplines. These themes 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. In addition to forming a framework for the curriculum, these ideas 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. 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. They will possess enthusiasm and positive attitudes toward science and maintain a lifelong interest in science.

The learning context is an integral part of the senior high science programs. It will 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 so students 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. They will appreciate the value of teamwork and make a positive contribution when working with others to solve problems and complete tasks.

SCIENCE 10

A. PROGRAM OVERVIEW

RATIONALE AND PHILOSOPHY

Science by its very nature is interesting, exciting and dynamic. Through the study of science, learners are given an opportunity to explore and understand the natural world and to become aware of the profound influence of science in their lives. Learning is facilitated by relating the study of science to what the learners already know, deem personally useful and consider relevant. Learning proceeds best when it originates from a base of concrete experiences presenting an authentic view of science. In Science 10, 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 learning about science and to appreciate it as an endeavour with practical impact on their own lives and on society as a whole.

Science is an experimental discipline requiring creativity and imagination. Methods of inquiry characterize its study. In Science 10, 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 their critical thinking skills. Through experimentation, problem-solving activities that include the integration of technology and independent study, students develop an understanding of the processes by which scientific knowledge evolves.

The Science 10 course places 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 that encourages them to make appropriate applications of scientific concepts to their daily lives and prepares them for future studies in science. Students are expected to participate actively in their own learning. An emphasis on the key concepts and principles of science provides students with a more unified view of the sciences and a greater awareness of the connections among them.

These science learnings will take varying amounts of time to acquire, depending on the individual learning styles and abilities of students. While the course is designed for approximately 125 hours, instructional time can be modified to meet the individual needs of students. Some students will require more than 125 hours, while others will require less.

GOALS

The major goals of the Science 10 course are:

- to develop in students an understanding of the 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 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.

Science 10 is an integrated academic course that helps students better understand and apply fundamental concepts and skills common to biology, chemistry, physics and the Earth sciences. Science 10 is a prerequisite for the 20 -level science courses. 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 course 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. LEARNER EXPECTATIONS

GENERAL LEARNER EXPECTATIONS

The general learner expectations outline the many facets of scientific awareness and serve as the foundation for the specific learner expectations covered in section C. The general learner expectations are developed in two categories: *program* expectations and *course* expectations.

PROGRAM GENERAL LEARNER EXPECTATIONS

Science 10 serves as the prerequisite for Biology 20-30, Chemistry 20-30, Physics 20-30 and Science 20-30. The *program* general learner expectations listed here apply to Science 10 in combination with each of the other four programs.

The *program* general learner expectations are broad statements of science attitudes, knowledge, skills and science, technology and society (STS) connections that students are expected to achieve in all of the senior high school science programs. These *program* general learner expectations are further refined through the *course* general learner expectations and then developed in specific detail through the study of individual units in Science 10 and each of the sciences at the 20 and 30 level. All expectations follow a progression from Science 10 through to each of the 30-level sciences, and though listed separately, are meant to be developed in conjunction with one another, within a context.

ATTITUDES

Students will be encouraged to develop:

- enthusiasm for, and a continuing interest in, science
- affective 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 and technological skills involving mathematics, problem-solving and process skills
- open-mindedness and respect for the points of view of others
- sensitivity to the living and nonliving environment
- appreciation of the roles of science and technology in our understanding of the natural world.

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 nonliving 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 that 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.

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. Students will also be expected to use teamwork, respect the points of view of others, make reasonable compromises, contribute ideas and effort, and lead when appropriate to achieve the best results. These processes involve many skills that are to be developed within the context of the program content.

Students will also be expected to be aware of the various technologies including information technology, computer software and interfaces that can be used for collecting, organizing, analyzing and communicating data and information.

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 these new ideas, when incorporated into 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 nonlinear 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 a problem
  - prepare required observation charts or diagrams, and carry out preliminary calculations
- Collecting and Recording
  - carry out the procedure and modify, if necessary
  - organize and correctly use apparatus and materials to collect reliable data
  - observe, gather and record data or information accurately according to safety regulations; e.g., Workplace Hazardous Materials Information System (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, using SI notation 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 affect on results
  - identify assumptions, attributes, biases, claims or reasons
  - identify main ideas
- Connecting, Synthesizing and Integrating

- predict from data or information, and determine whether or not these data verify or falsify the hypothesis and/or prediction
- formulate further testable hypotheses supported by the knowledge and understanding generated
- identify further problems or issues to be investigated
- identify alternative courses of action, experimental designs, and solutions to problems 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
- propose solutions to a problem being 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 biases, assumptions and perspectives
  - identify limitations of the data or information, and interpretations or conclusions, as a result of the experimental/research/project/design process or method used
  - evaluate and suggest alternatives and consider improvements to the experimental technique and design, the decision-making or the problem-solving process
  - evaluate and assess ideas, information and alternatives

CONNECTIONS AMONG SCIENCE, TECHNOLOGY AND SOCIETY

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 interrelationships among science, technology and society, including:

- the central role of 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 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: A Guide to Developing Students' Research Skills*, 1990.

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.

COURSE GENERAL LEARNER EXPECTATIONS

The *course* general learner expectations are specific to Science 10 and provide a bridge between the *program* general learner expectations and the specific learner expectations for each unit of study.

The attitudes expectations refer to those predispositions that are to be fostered in students. These expectations encompass attitudes toward science, the role of science and technology, and the contributions of science and technology toward society. The knowledge expectations are the major science concepts in the course. The skills expectations refer to the thinking processes and abilities associated with the practice of science, including understanding and exploring natural phenomena, and problem solving. The connections among science, technology and society expectations focus on the processes by which scientific knowledge is developed and on the interrelationships among science, technology and society.

The last *course* expectation links together the study of science, careers, everyday life and subsequent studies.

Although itemized separately, the attitudes, knowledge, skills and STS connections are meant to be developed together within one or more of the contexts listed.

Attitudes

Students will be encouraged to:

- appreciate the role of empirical evidence and models in science, and accept the uncertainty in explanations and interpretations of observed phenomena
- value the curiosity, openness to new ideas, creativity, perseverance and cooperative hard work required of scientists, and strive to develop these same personal characteristics
- appreciate the role of science and technology in advancing our understanding of the natural world, be open-minded and respectful of other points of view when evaluating scientific information and its applications, and appreciate that the application of science and technology by humankind can have both beneficial and harmful effects and can cause ethical dilemmas
- show a continuing interest in science, appreciate the need for computational competence, problem-solving and process skills when doing science, and value accuracy and honesty when communicating the results of problems and investigations
- appreciate the contributions of the various science disciplines and mathematics to our understanding of the natural world, and appreciate the multidimensional nature of issues arising from the interrelationships among science, technology and society.

Students should be able to:

Knowledge

- describe how energy and matter are transferred in all physical and biochemical changes; and identify energy transfers in the hydrologic cycle, photosynthesis and cellular respiration, the combustion of fuels, and energy conversion devices
- explain that energy and matter exist in many forms and are transferred, moved and conserved in and among physical, chemical and biological systems
- apply the law of energy conservation to energy transfer, calculating efficiency; and identify ways of conserving energy
- use the relationships among force, distance, work, energy and time to describe how energy is measured; and compare the functioning of common energy conversion devices
- apply the principle of conservation of matter to calculations and investigations into chemical changes that produce substances useful to

society and/or may have unpredictable effects on the environment

- describe atoms, ions and molecules; and investigate the chemical and physical properties of common elements and compounds; and apply the classification system to identify elements, ionic and molecular compounds, and common household substances

Skills

- perform investigations, tasks and procedures, designed by others, that have a few, simple variables, yield direct evidence, and require empirically-based explanations
- collect, verify and organize data into tables, graphs and diagrams designed by others, and put into written form; and describe findings or relationships, using scientific vocabulary, notation and concepts
- plot data that yield straight-line graphs; and use appropriate SI notation, fundamental and derived units and formulas; and determine slopes of, and areas under, straight-line graphs
- use mathematical language of ratio and proportion, and simple equations, to solve numerical problems; and use chemical equations and nomenclature to communicate scientific ideas, relationships and concepts

Connections Among Science, Technology and Society

- list for a given instance, appropriate and relevant examples that relate direct scientific evidence to a theory; and describe the limitations of science and technology in answering all questions and solving all problems
- list for a given instance, appropriate and relevant examples of technological solutions to practical problems; and describe the functioning of technologies, using scientific principles; and relate the ways in which science and technology advance one another
- identify for a given instance, appropriate and relevant examples that show how science and technology are influenced and supported by society; and describe the responsibility of society through science and technology to protect the environment and use natural resources wisely
- identify subject-related careers and apply the skills and knowledge acquired in Science 10 to everyday life and to related and new concepts in subsequent studies of science.

SPECIFIC LEARNER EXPECTATIONS

LEARNING CYCLE

The specific learner expectations consist of the knowledge, skills and attitudes that are to be addressed in Science 10. The use of the learning cycle allows students to progress from:

- an introduction framing the lesson in an STS connection relevant to the lives of the learners, and makes connections between past and present learning experiences, as well as anticipates activities to focus students' thinking on the learning outcomes of the activity, to
- the experiential exploration of new content that provides students with a common base of experiences within which they identify and develop key concepts, processes and skills, through
- a hypothesis-building phase where concepts are developed to describe a particular aspect of their experiential exploration, and opportunities are provided to communicate their conceptual understanding, or demonstrate their skills or behaviours, to
- an elaboration phase that extends understanding of key concepts and allows further opportunities to practise desired skills and problem-solving strategies, to
- an application phase where the hypotheses, vocabulary and patterns previously developed are applied to new situations and related to key concepts and principles of science, to
- a final evaluation of the significance of the new learning in an STS context to assess their

understanding and abilities, and provide opportunities for teachers to evaluate student progress toward achieving the curriculum standards.

In science, students examine phenomena in a variety of topics to show the relationships among the sciences. Wherever possible, examples should be framed in the context of the learners' own experiences to enable them to make the connections between scientific knowledge and the society around them, the technology that societies have developed, and the nature of science itself.

COURSE OVERVIEW

The Science 10 course emphasizes four of the key concepts of science: *change, energy, matter* and systems. The concepts of *diversity* and *equilibrium* are included as well but receive less emphasis. These themes provide a means of showing the connections among the scientific disciplines, and provide a framework for teachers to show students how individual sections of the course relate to the big ideas of science.

In addition to developing a solid understanding of the fundamental science concepts and principles, Science 10 has the goal of educating students about the nature of science and technology, and the interaction between science and technology. Students must be aware of the tremendous impact of science and associated technology on society, but at the same time they must be aware of the roles and limitations of the sciences and technology in problem solving in a societal context.

The major concepts allow connections to be drawn among the four units of the course.

Science 10 consists of four units of study:

Unit 1: Energy from the Sun
Unit 2: Energy and Matter in Living Systems
Unit 3: Energy and Matter in Chemical Change
Unit 4: Change and Energy.

Unit 1 focuses on the role of radiant energy from the Sun in sustaining life and driving weather *systems* on Earth. In Unit 2, the processes by which *energy* and *matter* are exchanged between living *systems* and their environment are studied, and change is illustrated by the growth of living organisms. Unit 3 investigates the *changes* in *energy* and *matter* that occur during chemical reactions. Unit 4 examines different forms of *energy* and the principles that govern *energy* transformations.

UNIT 1
ENERGY FROM THE SUN

OVERVIEW

Science Themes: *Energy, Matter* and *Systems*

In Unit 1, students investigate how radiant *energy* from the Sun sustains life and drives weather *systems* on Earth. The properties of water are studied and compared with the properties of other forms of *matter*. Students investigate the role of water in moderating the *changes* in the Sun's *energy* as it moves through the biosphere.

This unit builds on Science 8, Unit 5: Growing Plants; and Science 9, Unit 3: Heat Energy: Transfer and Conservation, and provides students with a foundation for the study of *ecosystems* and alternative *energy* sources in the 20- and 30-level science courses.

The three **major concepts** developed in this unit are:

- *energy* from the Sun sustains life on Earth
- the properties of water, relative to other forms of *matter*, profoundly influence the nature of life on Earth
- *energy* from the Sun determines climate and drives weather *systems*.

In this unit, *students will develop* an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- collecting and recording
- organizing and communicating
- analyzing data from investigations of the Sun's *energy* and the properties of water.

The **STS connections** in this unit illustrate:

- the functioning of products or processes based on scientific principles
- the use of technology to solve practical problems
- the limitations of scientific knowledge and technology.

ATTITUDES

Students will be encouraged to:

- develop a questioning attitude concerning natural phenomena
- appreciate the importance of solar *energy* in sustaining life and driving weather *systems* on Earth
- appreciate the importance of water in determining the nature of life on Earth
- recognize that scientific knowledge of meteorological phenomena is cumulative and subject to *change*
- recognize the limits of current scientific theories in predicting natural phenomena, such as weather.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. *Energy* from the Sun sustains life on Earth.	• energy from the Sun sustains life on Earth, by extending from Science 8, Unit 5, the life processes of plants, and by: • defining photosynthesis as the process by which green plants (producers) put together carbon dioxide and water to store energy and form carbohydrates and oxygen • defining aerobic respiration as the process by which organisms (consumers) release energy by reacting on carbohydrates and oxygen to form carbon dioxide and water • describing how photosynthesis and aerobic respiration are the reverse of each other • indicating that all life on Earth exists in the biosphere, a relatively thin spherical shell having an approximate thickness of 15 kilometres • indicating that the biosphere exists within the three major spherical layers of Earth—the atmosphere, the hydrosphere and the lithosphere • explaining how energy flow through the biosphere is facilitated by different types of organisms; i.e., producers, consumers and decomposers • defining open, closed and isolated systems; i.e., – open system: exchanges both energy and matter with its surroundings – closed system: exchanges energy but not matter with its surroundings – isolated system: does not exchange matter or energy with its surroundings.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that energy from the Sun sustains life in the biosphere through the processes of photosynthesis and respiration, within the context of:
• performing an experiment to demonstrate the role of light energy in the production of carbohydrates and oxygen by green plants	• tracing the energy contained in a typical student lunch to its source in the Sun, using the laws of thermodynamics
• identifying the manipulated, responding and controlled variables (variables held constant) in an experimental investigation of photosynthesis	OR
• distinguishing between a controlled variable and a control experiment (an experiment carried out under the same conditions as another experiment except for one factor)	• describing 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; e.g., global deforestation
• designing a closed system to illustrate the dynamic balance between photosynthesis and respiration	OR
• tracing the flow of energy through the biosphere, interrelating autotrophic and heterotrophic matter needs by comparing representative producers and consumers.	• investigating the ways in which technology advances science; e.g., attempts to establish artificial ecosystems in a large closed system, such as Biosphere II
	OR
	• any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
2. The properties of water, relative to other forms of *matter*, profoundly influence the nature of life on Earth.	• the properties of water, including surface tension, melting point, boiling point, specific heat capacity, heat of fusion, heat of vaporization, expansion on freezing, and maximum density at 4°C, profoundly influence the nature of life on Earth, by: • extending from Science 9, Unit 3, that heat is a form of energy and may be quantified using $Q=mc\Delta T$ • calculating the thermal energy involved when a measured mass of water undergoes a measured temperature change • calculating the thermal energy involved when a measured mass of water undergoes a phase change • relating the hydrologic cycle to solar energy • relating the properties of water to the maintenance of constant body temperature • indicating why ice forms on the surface of water, and relating this to the winter survival of aquatic organisms • describing how the properties of water are due to the polar nature of the water molecule • explaining the effect of thermal energy on matter, using the kinetic molecular theory as a simple mechanical model • describing temperature changes in terms of changes in the kinetic energy of the molecules of a substance • describing phase changes in terms of the kinetic molecular theory.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that the properties of water, including surface tension, melting point, boiling point, specific heat capacity, heat of fusion, heat of vaporization, expansion on freezing, and maximum density at 4°C, profoundly influence the nature of life on Earth, including the maintenance of constant body temperature, the winter survival of aquatic organisms; and the operation of the hydrologic cycle, within the context of:
• observing and recording some of the physical properties of water • collecting and graphing data showing the effect of heat on the temperature of water • performing an experiment to determine the heat of fusion of ice • calculating any variable in the equation, $Q=mc\Delta T$, given the other three variables • graphing and analyzing data showing how the density of water varies with temperature • designing an experiment to investigate the change in volume of water upon freezing.	• explaining the scientific principles involved in the technologies that use water to maintain a uniform temperature in buildings OR • describing the use of technology to solve practical problems; e.g., construction methods that account for the expansion of water upon freezing; and technologies that use solar energy to desalinate water OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
3. *Energy* from the Sun determines climate and drives weather *systems.*	• energy from the Sun determines climate and drives weather systems, by: • explaining the principal factors that determine climate; i.e., large bodies of water, ocean currents, latitude, surface characteristics • explaining the significance of the differential solar heating of equatorial and polar regions in the transfer of thermal energy • explaining weather changes in terms of pressure systems, cold and warm fronts, and the Coriolis effect • explaining a local weather phenomenon; e.g., chinooks, thunderstorms, hailstorms or tornadoes.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that weather systems, such as chinooks, thunderstorms, hailstorms and tornadoes, are driven by energy from the Sun through the mechanisms of vertical air currents, pressure systems, cold and warm fronts and the Coriolis effect, and that climate is strongly effected by large bodies of water, ocean currents and latitude, within the context of:
• comparing mean monthly temperature data for cities of similar latitude and accounting for any differences • constructing and interpreting climate graphs • designing an experiment to investigate the heating effect of solar energy • performing an experiment to investigate the heat changes involved in the compression and expansion of air • communicating meteorological data in SI units; e.g., temperature, wind velocity, atmospheric pressure, precipitation • interpreting weather maps of local weather • comparing weather forecasts to observed weather.	• describing the use of technology to solve practical problems; e.g., the operation of weather satellites in monitoring weather systems OR • describing the limitations of scientific knowledge and technology; e.g., how more accurate weather predictions could benefit millions of people globally OR • describing the technology used to monitor levels of atmospheric gases OR • describing the central role of experimental evidence in the accumulation of knowledge, and the way in which proposed theories may be supported, modified or refuted; e.g., using a greenhouse as a model of Earth's atmosphere OR • any other relevant context.

UNIT 2
ENERGY AND MATTER IN LIVING SYSTEMS

OVERVIEW

Science Themes: *Energy, Matter* and *Systems*

In Unit 2, students investigate how *energy* and *matter* are exchanged between living *systems* and their environment, and examine the *changes* involved in the growth of living organisms. The energetics of diffusion, osmosis and active transport are analyzed. The limitations that diffusion places on growth, and the significance of transport in multicellular organisms are examined.

This unit builds upon Science 8, Unit 5: Growing Plants, and Unit 6: Interactions and Environments, and continues from Science 10, Unit 1: Energy from the Sun, the study of photosynthesis and respiration. The knowledge, skills and attitudes developed in this unit provide students with a sound background for the further study of living *systems* in Biology 20 and Science 20.

The four **major concepts** developed in this unit are:

- the cell is the basic unit of living *systems*
- growth is a major feature of living *systems*, and a major limitation to growth is the surface area to volume ratio of the cell
- the cell is an open *system* exchanging *energy* and *matter* with the environment
- organisms provide for *energy* and *matter* needs at a distance from the organism's interface with the environment.

In this unit, ***students will develop*** an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- collecting and recording
- organizing and communicating
- analyzing data from investigations of living *systems*.

The **STS connections** in this unit illustrate:

- 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.

ATTITUDES

Students will be encouraged to:

- appreciate the unity of science through the application of physical and chemical principles to biological *systems*
- appreciate that biological principles emerge from the investigation of the structure and function of living *systems*
- appreciate that many fundamental biological processes operate at both the cellular and higher levels of organization
- appreciate that the maintenance of homeostasis relies on *equilibria* within the organism and between the organism and its environment
- develop a curiosity to obtain a deeper understanding of biological *systems*
- appreciate that our knowledge of biology has been enhanced by the application of technology
- appreciate that the application of technology can have beneficial and harmful effects on biological *systems*.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. The cell is the basic unit of living *systems.*	• the cell is the basic unit of living systems, by: • identifying and briefly describing the structure and function of the nucleus, nucleoid, endoplasmic reticulum, Golgi apparatus, lysosome, vacuole, mitochondrion, chloroplast, ribosome, cytoskeleton and cell wall, where present, in bacteria, plant and animal cells • identifying, and briefly describing, the structure and function of the cell membrane in relation to cell equilibrium, and active and passive transport • describing the similarities and differences in the structure and function of prokaryotic and eukaryotic cells • describing the structure and use of a compound microscope.

SKILLS	STS CONNECTIONS

SKILLS

Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:

- drawing analogies between the evidence for division of labour within cells to services in communities
- identifying cellular structures in living and prepared materials by using dissecting and compound microscopes and by examining electron micrographs
- preparing plant and animal material for microscopic examination, using stains and observing the materials
- calculating magnification, field of view and scale
- calculating the size of a cell from a knowledge of microscope magnification power and field of view.

STS CONNECTIONS

Students should be able to demonstrate the interrelationships among science, technology and society, by:

- understanding that the cell is the basic unit of life; and describing the structure and function of the cell membrane and selected organelles in both prokaryotic and eukaryotic cells, and by preparing tissue for observation, observing and identifying cellular structures, and estimating size and magnification, within the context of:
  - describing how advancements in knowledge of cell structure increased as a direct result of developments in microscope technology, including electron microscopes

  OR

  - assessing the needs, interests and financial support of society on the development of the electron microscope, a Canadian invention

  OR

  - any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
2. Growth is a major feature of living *systems*, and a major limitation to growth is the surface area to volume ratio of the cell.	• growth is a major feature of living systems, and a major limitation to growth is the surface area to volume ratio of the cell, by: • describing what is meant by growth in terms of both an increase in the number of cells by fission or mitosis, and the increase in volume or mass of a cell or organism • describing how the surface area to volume ratio of a cell might limit its growth, and inferring the value of multicellularity in enhancing the ability to use nutrients • explaining how division of labour occurs within a single cell and, after the process of differentiation, in a multicellular organism.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that growth is a major feature of living systems; and explaining how surface area to volume ratio is the major limitation to growth, describing cell division, multicellularity and division of labour; and by observing growing plant cells and calculating and comparing surface area to volume ratios in various organisms, within the context of:
• observing and recording macroscopic and microscopic changes in a growing plant for evidence of differentiation	• describing the use of technology to solve practical problems; e.g., bacterial products or processes used in research and industry
• calculating and graphing the surface area to volume ratios of a variety of model cell sizes and shapes, when one variable is changed at a time	OR
• comparing the surface area to volume ratio of various organisms and relating the findings to the organisms' metabolic rates; e.g., hummingbird or shrew compared with elephant or whale.	• identifying and explaining examples of surface area maximization in technological and natural systems that facilitate transfer of thermal energy, gases, nutrients or wastes
	OR
	• any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
3. The cell is an open *system* exchanging *energy* and *matter* with the environment.	• the cell is an open system exchanging energy and matter with the environment, by extending from Science 8, Unit 5, the life processes of plants, and by: • describing how materials diffuse across a cell membrane in terms of concentration gradients • describing how the semipermeable nature of the cell membrane allows the process of osmosis • describing, in general terms, how the energy in light is converted to chemical energy • describing, in general terms, how carbon dioxide molecules in solution, or in the air, are fixed as carbohydrates in the plant chloroplasts, using the stored light energy • describing how adenosinetriphosphate (ATP) is used to do the work of transporting substances across membranes against their concentration gradients; i.e., active transport, endocytosis and exocytosis • describing, in general terms, how the energy for active transport is derived from photosynthesis and respiration in the form of ATP.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that the cell is an open system, using both active and passive processes to exchange energy and matter with the environment, and that the energy for active transport is derived from photosynthesis and respiration in the form of ATP; and by performing experiments demonstrating matter exchange processes in plants and dialysis tubing, and researching types of nutrient acquisition in selected plants and animals, within the context of:
• investigating the different action of a sucrose solution and a starch solution when placed in separate dialysis bags and immersed in water, and inferring why the solutions behave differently • performing an experiment to demonstrate the phenomena of plasmolysis and deplasmolysis in plant cells; e.g., staminal hairs or aquatic leaf cells, and describing the observed events in terms of the tonicity of the cells and solutions • inferring how biochemical interconversion of starch and glucose might regulate the turgor pressure of cells • observing and/or researching nutrient acquisition at the cellular level.	• explaining the scientific principles behind eating solid food and organism nutrition OR • explaining how a knowledge of diffusion and osmosis can be used in technological applications; e.g., desalination of sea water, peritoneal or mechanical dialysis OR • describing how gas compression technology has been used to solve the practical problems encountered by humans working in high altitudes or deep oceans, and explaining what happens in altitude sickness and caisson disease OR • summarizing articles, based on the scientific principles of energy and matter exchange, the latest scientific and/or technological developments; e.g., kidney research OR • explaining the scientific principles and processes involved in oral rehydration therapy used to treat cholera OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
4. Organisms provide for *energy* and *matter* needs at a distance from the organism's interface with the environment.	• organisms provide for energy and matter needs at a distance from the organism's interface with the environment, by extending from Science 9, Unit 1, that living things show a diversity of structural adaptation, and by:
	• comparing how selected organisms transport nutrients and wastes over short and long distances, and discussing the differences in terms of the structure and function of the organisms; e.g., unicellular and multicellular
	• comparing how selected organisms acquire nutrients and remove wastes, and discussing the differences in terms of the structure and function of the organisms; e.g., unicellular and multicellular
	• comparing how selected organisms exchange gases, and discussing the differences in terms of the structure and function of the organisms; e.g., unicellular and multicellular
	• explaining the movement of water in plants in terms of the polar nature of water.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding how multicellular organisms exchange energy and matter between their cells and the environment, describing multicellular transport mechanisms, comparing nutrient acquisition, waste excretion, and gas exchange; and by observing cytoplasmic streaming in the *Amoeba*, water movement in plants, and observing and comparing transport systems in diverse pairs of organisms, within the context of:
• observing and describing the appearance of cytoplasmic streaming in *Amoeba* or a plant cell, and inferring similar movement in most cells of a multicellular organism	• explaining biological processes in terms of the scientific principles involved; e.g., nutrient distribution in multicellular organisms
• identifying diverse pairs of organisms and comparing them with respect to transport systems; e.g., *Amoeba* and giraffe, a single-celled alga and a redwood tree	**OR**
• observing, recording and explaining the movement of water in plants.	• describing the use of technology to solve practical problems; e.g., the use of vacuum-tapping system technology of sap recovery while taking advantage of the natural transport system of maple trees
	OR
	• describing the processes involved in the uptake and distribution of systemic pesticides in the treatment of plant diseases; e.g., the fungicide used to treat Dutch elm disease
	OR
	• any other relevant context.

UNIT 3
ENERGY AND MATTER IN CHEMICAL CHANGE

OVERVIEW

Science Themes: *Change, Energy* and *Matter*

In Unit 3, students investigate how *energy* and *matter* are involved in chemical *change*. Students study the patterns among the properties of the elements that form the basis of the periodic table. A simple model of the atom is presented to explain the chemical properties of *matter* and the *energy* effects of chemical *change*. To deal with the vast array of compounds created by combining elements, the International Union of Pure and Applied Chemistry (IUPAC) system of chemical nomenclature is introduced.

This unit builds on Science 8, Unit 1: Solutions and Substances; and Science 9, Unit 5: Chemical Properties and Changes, and provides students with a foundation for the further study of chemical *change* in Science 20 and Chemistry 20.

The five **major concepts** developed in this unit are:

- *matter* is classified on the basis of its properties
- *matter* has a well-defined underlying structure
- elements combine to form a vast array of compounds
- *energy* is involved in each *change* that *matter* undergoes
- *matter* is conserved in chemical *changes*.

In this unit, *students will develop* an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- collecting and recording
- organizing and communicating
- analyzing data from investigations of chemical *change*.

The **STS connections** in this unit illustrate:

- the ways in which science advances technology and technology advances science
- 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.

ATTITUDES

Students will be encouraged to:

- appreciate the orderliness of nature and the characteristic pattern in the properties of *matter*
- appreciate that careful and precise observations form the basis for generalizations about the nature of *matter*
- tolerate the uncertainty in our explanations of the nature of *matter*
- value the contribution of science and technology to our understanding of the nature of *matter*
- value the need for safe handling and disposal of chemicals
- demonstrate an awareness of the impact that humankind has had on the environment through the manipulation of *matter* for personal and industrial use
- appreciate the benefits that have resulted from applications based on chemical principles.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. *Matter* is classified on the basis of its properties.	• matter is classified on the basis of its properties, by extending from Science 8, Unit 1, and Science 9, Unit 5, the major categories of matter (e.g., pure substance, mixture, element, compound, solution) and the differences between physical and chemical properties, and by: • explaining that matter is everything that has mass and occupies space • explaining the classification of the first 20 elements in the periodic table in terms of chemical properties • predicting the properties of elements from their position on the periodic table, and the placement of elements on the periodic table from their properties • identifying the elements that are most prevalent in living systems.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding the classification of matter based on physical and chemical properties, the placement of elements on the periodic table, identifying elements prevalent in living systems; and by handling reactive materials safely, using separation techniques, and investigating and classifying matter, using laboratory tests, within the context of:
• handling reactive materials safely • using observation and experimentation to study the properties of matter, and to classify various examples of matter • observing physical and chemical properties of representative elements, noting the patterns.	• describing how WHMIS symbols are used to classify potentially hazardous materials; and explaining the need for such systems to protect ourselves and the environment from harm OR • describing some of the physiological effects of heavy metals, such as lead or mercury, and the possible sources of contamination in everyday life; and explain the limitations of scientific knowledge and technology in providing complete answers to all questions OR • explaining why most metals must be separated from their ores and protected from corrosion, an example of the functioning of products or processes based on scientific principles OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
2. *Matter* has a well-defined underlying structure.	• matter consists of atoms, ions and molecules, by: • providing definitions for the following chemical species: atoms (isotopes), ions, molecules • indicating relative size, charge and mass of electrons, protons and neutrons • indicating the relative sizes of atoms, ions and molecules • describing the extent to which we are able to "observe" chemical species with modern technology.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding what is meant by the following chemical species: atoms (isotopes), ions and molecules, their relative size and the extent to which modern technology allows us to "observe" them; and by building models of atomic structure, within the context of:
• describe in words, diagrams and /or models, the structure of the atoms of the first 20 elements, including protons, neutrons and electrons.	• illustrating, with examples, how isotopes are used in medical research and treatment as evidence of the functioning of products and processes based on scientific principles OR • outlining the merits of spending public money on investigating atomic structure, and the influence of the needs, interests and financial support of society on scientific and technological research OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
3. Elements combine to form a vast array of compounds.	• elements combine to form compounds that have characteristic properties and are assigned individual names, by: • differentiating, on the basis of properties (conductivity, pH) and formulas, between ionic and molecular compounds, including acids and bases • identifying the role of several compounds in living systems; i.e., water, hydrochloric acid, glucose, ATP, fats • naming and writing formulas for common ionic and molecular compounds and acids, using a periodic table and a list of polyatomic ions • using a solubility chart to determine if an ionic compound will dissolve in water.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that elements combine to form compounds; identifying compounds important to living systems; providing names and formulas for compounds; and by investigating and classifying compounds, using laboratory tests, within the context of:
• investigating the properties of representative ionic and molecular compounds, including acids and bases, in laboratory experiments, and in resources, such as a chemistry handbook • using equipment, such as Bunsen burners and laboratory glassware, correctly and safely • handling and disposing of chemicals in a safe, responsible manner.	• describing several compounds that are essential to human health and several that are hazardous to human health or the environment; and explaining the need for such knowledge to protect ourselves and the environment from harm **OR** • explaining the importance of the International Union of Pure and Applied Chemistry (IUPAC) system of naming compounds in terms of the work that scientists do and the need to communicate clearly **OR** • describing the disposal problem related to used materials in terms of the ability and responsibility of society to protect the environment and use natural resources judiciously to ensure quality of life for future generations **OR** • outlining safe methods for handling potentially hazardous substances in the home and laboratory; and explaining the need for such knowledge to protect ourselves and the environment from harm **OR** • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
4. ***Energy*** is involved in each ***change*** that ***matter*** undergoes.	• energy is involved in each change that matter undergoes, by: • comparing and contrasting physical and chemical changes • describing evidence of chemical reactions; i.e., energy change, formation of a gas, formation of a precipitate, colour change, odour change • differentiating between endothermic and exothermic changes • identifying types of chemical reactions; i.e., formation, decomposition, combustion, single replacement and double replacement • writing word equations for chemical reactions that occur in living and nonliving systems; e.g., • carbon dioxide+water+energy→glucose+oxygen • glucose+oxygen→carbon dioxide+water+energy • zinc+sulfur→zinc sulfide+energy • water+energy→hydrogen+oxygen • methane+oxygen→carbon dioxide+water +energy • copper+silver nitrate→silver+copper(II) nitrate+energy • lead(II) nitrate+potassium iodide→potassium nitrate+lead(II) iodide+energy • translating word equations into chemical equations and translating chemical equations into word equations.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by: • performing experiments that illustrate chemical changes, including endothermic and exothermic examples.	*Students should be able to demonstrate the interrelationships among science, technology and society, by:* • understanding that energy is involved in all physical and chemical transformations of matter; and identifying and writing word /chemical equations for chemical reactions; and by performing experiments that illustrate chemical changes, within the context of: • providing examples of household, commercial and industrial processes that use physical and/or chemical changes to produce useful substances and energy OR • identifying chemical reactions that are harmful to the environment; e.g., destruction of the ozone layer by chlorofluorocarbons, formation of acid rain and greenhouse gases; and explaining 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 OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
5. *Matter is conserved in chemical changes.*	• the conservation of mass in chemical changes can be illustrated and quantified, by: • outlining experiments, such as van Helmont's and Lavoisier's, that establish the law of conservation of mass • writing chemical equations that include the state of matter for each substance, and balancing the equations in terms of chemical species and moles; predicting the products of reactions is not required.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that mass is conserved in chemical changes by writing balanced chemical equations; and by performing experiments, doing measurements and calculations to illustrate the conservation of matter in chemical change, within the context of:
• performing an experiment that demonstrates the principles behind Lavoisier's experiments on combustion, which led to the conclusion that burning substances gain mass by combining with oxygen from the air	• explaining the significance of using technologies in analytical chemistry, such as balances, calculators and computers as examples of how science advances technology and technology advances science
• illustrating that mass is conserved during a chemical reaction in a closed system	OR
• predicting relative solubility of selected ionic compounds using a solubility chart and /or experimentation.	• any other relevant context.

UNIT 4
CHANGE AND ENERGY

OVERVIEW

Science Themes: *Change* and *Energy*

In Unit 4, students quantitatively investigate *energy changes* and develop their understanding of *energy* transformation and conservation. The unit concludes with a project in which students design and build a simple *energy* conversion device and evaluate its efficiency.

This unit builds on Science 7, Unit 3: Force and Motion, and Unit 4: Temperature and Heat Measurement; Science 9, Unit 3: Heat Energy: Transfer and Conservation, and extends the concepts of *energy* transformation introduced in Unit 1, and treated in their biological and chemical contexts in Unit 2 and Unit 3. The knowledge, skills and attitudes developed in this unit provide students with a foundation for the study of energy and conservation topics in Science 20 and Physics 20.

The four **major concepts** developed in this unit are:

- *energy* is always associated with *change*
- *energy* can be transformed from one form to another
- *energy* cannot be created or destroyed, only converted from one form into another
- useful *energy* diminishes during any *energy* transformation.

In this unit, *students will develop* an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- collecting and recording
- organizing and communicating
- analyzing data from investigations of *energy* change.

The **STS connections** in this unit illustrate:

- the functioning of products or processes based on scientific principles
- the use of technology to solve practical problems
- the ability and the responsibility of society, through science and technology, to protect the environment and use natural resources judiciously to ensure quality of life for future generations.

ATTITUDES

Students will be encouraged to:

- develop a positive attitude toward mathematical, communication and scientific processes and skills in the study of *energy*
- appreciate the need for computational competence in quantifying *energy* and *energy* transfers
- respect evidence when interpreting observed phenomena related to *energy*
- appreciate that science is a disciplined way to develop explanations and descriptions about *energy* in the natural and technological world
- accept uncertainty in our descriptions and explanations of observations related to *energy* in the physical world.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. *Energy is always associated with change.*	• energy is always associated with change, by extending from Science 8, Unit 2, the definition of mechanical work, and quantifying the work done on /by an object, using $W=Fd$; by extending from Science 7, Unit 3, the notions of force, mass and weight; and by: • defining kinetic energy as energy due to motion, and potential energy as energy due to position or condition • illustrating, by use of examples, that energy exists in a variety of forms; e.g., mechanical, chemical, electrical, thermal, nuclear, solar • illustrating, by use of examples, that the Sun is the source of most energy forms on Earth • describing one-dimensional uniform motion, using words, graphs and formulas; e.g., $v=\frac{\Delta d}{\Delta t}$ • defining energy as the property of a system that is a measure of its capacity for doing work, and work as the transfer of energy • deriving the SI unit of energy and work, the joule, from fundamental units.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:* • understanding that energy, existing in a variety of forms, is always associated with change, and that the Sun is the source of most energy forms on Earth; and describing the relationship between energy and work, and one-dimensional motion, using graphical and mathematical techniques; and by tracing the flow of energy from the Sun; and by gathering, numerically analyzing and graphing data relevant to the relationships among distance, speed, time and force, distance and work, within the context of:
• making a synopsis of energy as it has been discussed in earlier units • tracing the flow of energy from the Sun to the lighting system in the school, identifying what changes are taking place at each stage of the process • performing an experiment to determine the relationships among distance, speed and time for uniform motion • calculating the slope of the line in a distance–time graph to determine speed • calculating the area under the line in a speed–time graph to determine the distance travelled • calculating the area under the line in a force–distance graph to determine work done.	• discussing, qualitatively, the importance of the Sun as an energy source for life on Earth in terms of the energy conversion processes involved OR • describing the functioning technologies that address the problem of providing current energy sources OR • any other relevant context

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
2. *Energy* can be transformed from one form to another.	• energy can be transformed from one form to another, by extending from Science 7, Unit 4, that thermal energy can be derived from a variety of sources; and by:
	• recognizing that potential energy is only useful when it is transformed to some form of kinetic energy
	• illustrating, by use of examples, that energy transfers produce measurable changes in motion, shape or temperature of matter
	• defining gravitational potential energy as the work done on a mass against gravity, and quantifying gravitational potential energy, using $E_p=mgh$
	• quantifying kinetic energy, using $E_k=1/2mv^2$
	• recognizing chemical energy as a form of potential energy; e.g., glucose, ATP, gasoline, lead–acid battery
	• quantifying electrical energy, using $E_e=Pt$
	• analyzing units to describe the kilowatt hour as a unit of energy, and the watt as a unit of rate of energy transfer or a unit of rate of doing work.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	***Students should be able to demonstrate the interrelationships among science, technology and society, by:***
	• understanding that energy can be transformed from one form to another, and quantifying these transformations; and explaining that energy transfers produce measurable changes in motion, shape or temperature of matter; and by empirically investigating energy conversions; and by calculating the energy consumption of selected technologies given relevant data, within the context of:
• calculating the energy consumption of selected household technologies; e.g., toaster, microwave oven, refrigerator • discussing an experiment to demonstrate the conversion of chemical potential energy to thermal energy, involving a combustion reaction • performing an experiment to demonstrate the conversion of energy from a potential form to a kinetic form, using a pendulum • performing an experiment to demonstrate the equivalency of work done on an object, and the resulting kinetic energy.	• describing, qualitatively, current technologies used to convert energy from one form to another; e.g., hydroelectric and coal-burning power stations, solar cells **OR** • describing, qualitatively, technological devices that use chemical potential energy as an energy source in terms of their function and the practical problems addressed **OR** • analyzing, in terms of scientific principles, the energy transfers occurring as an automobile or a bicycle comes to a stop **OR** • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
3. *Energy* cannot be created or destroyed, only converted from one form into another.	• conservation of energy is a fundamental law of nature, by: • stating the law of conservation of energy as "the sum of initial energies is equal to the sum of final energies" • recognizing the first law of thermodynamics as a statement of the law of conservation of energy • describing, by use of examples, that thermal energy will, of its own accord, flow from a hotter body to a cooler body, and recognizing this as a formal statement of the second law of thermodynamics • comparing the mechanism of diffusion to thermal energy transfer according to the second law of thermodynamics.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that energy cannot be created or destroyed, and that thermal energy flows, of its own accord, from a hotter body to a cooler one; and by tracing energy conversions in selected systems; and by experimentally investigating conservation of energy in a closed system, and the similarities between diffusion and thermal energy transfer, within the context of:
• tracing the stages of energy conversion in a system; e.g., a power plant or food chain, and identifying the sources of energy loss • performing an experiment to demonstrate the similarities between diffusion and thermal energy transfer.	• describing, qualitatively, the energy transfer processes in terms of scientific principles in various conversion systems; e.g., refrigerator, heat pump, thermal power plant, food chain OR • commenting on the feasibility of perpetual motion machines in terms of the laws of thermodynamics OR • comparing and contrasting the energy transfers and technologies in a hydroelectric plant and a thermal power plant in terms of the laws of thermodynamics OR • discussing the role of alternative energy sources to generate energy in Alberta considering society's responsibility to protect the environment and use natural resources judiciously OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
4. Useful *energy* diminishes during any *energy* transformation.	• the amount of useful energy diminishes during any energy transformation, by:
	• interpreting empirical data from a study of energy conversions
	• explaining that energy conversion processes have different efficiencies, based on total energy input compared to the net useful energy output
	• defining efficiency as a measure of the useful work compared to the total energy put into an energy conversion process
	• defining inefficiency as the fraction of energy lost as wasted heat in the conversion process
	• describing techniques for reducing waste of energy, in a common household device.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding that during any energy transformation the useful energy diminishes, and describing thermal energy waste reduction techniques; and by quantifying the efficiency of common heating devices; and performing experiments demonstrating the conversion of mechanical and electrical energy into thermal energy, within the context of:
• conducting an investigation in which the efficiency of common technological devices used to heat a specific amount of water is quantified and evaluated • performing an experiment in which mechanical energy is converted into heat energy • designing and building an energy conversion device and calculating its efficiency.	• comparing and contrasting the energy content of fuels used in thermal power plants in Alberta on the basis of scientific principles and the need to protect the environment and use our natural resources judiciously OR • discussing the role of efficiency of energy conversions to encourage responsible energy use in order to protect our environment and use our natural resources judiciously OR • discussing the impact of displaying energy consumption labels on household appliances in terms of the needs and interests of society OR • any other relevant context.

SCIENCE 20–30

A. PROGRAM OVERVIEW

RATIONALE AND PHILOSOPHY

Science by its very nature is interesting, exciting and dynamic. Through the study of science, learners are given an opportunity to explore and understand the natural world and to become aware of the profound influence of science in their lives. Learning is facilitated by relating the study of science to what the learners already know, deem personally useful and consider relevant. Learning proceeds best when it originates from a base of concrete experiences presenting an authentic view of science. In Science 20–30, 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 learning about science and to appreciate it as an endeavour with practical impact on their own lives and on society as a whole.

Science is an experimental discipline requiring creativity and imagination. Methods of inquiry characterize its study. In Science 20–30, 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 their critical thinking skills. Through experimentation, and problem-solving activities that include the integration of technology and independent study, students develop an understanding of the processes by which scientific knowledge evolves.

The Science 20–30 program places students at the centre. Students are active learners and will assume increased responsibility for their learning as they work through the program. A thorough study of science is required to give students an understanding that encourages them to make appropriate applications of scientific concepts to their daily lives and prepares them for future studies in science. Students are expected to participate actively in their own learning. An emphasis on the key concepts and principles of science provides students with a more unified view of the sciences and a greater awareness of the connections among them.

These science learnings will take varying amounts of time to acquire, depending on the individual learning styles and abilities of students. While each course is designed for approximately 125 hours, instructional time can be modified to meet the individual needs of students. Some students will require more than 125 hours, while others will require less.

GOALS

The major goals of the Science 20–30 program are:

- to develop in students an understanding of the 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 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.

Science 20–30 is an integrated academic program that helps students better understand and apply fundamental concepts and skills common to biology, chemistry, physics and the Earth sciences. 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. LEARNER EXPECTATIONS

GENERAL LEARNER EXPECTATIONS

The general learner expectations outline the many facets of scientific awareness and serve as the foundation for the specific learner expectations covered in section C. The general learner expectations are developed in two categories: *program* expectations and *course* expectations.

PROGRAM GENERAL LEARNER EXPECTATIONS

The *program* general learner expectations are broad statements of science attitudes, knowledge, skills and science, technology and society (STS) connections that students are expected to achieve in all of the senior high school science programs. These *program* general learner expectations are further refined through the *course* general learner expectations and then developed in specific detail through the study of individual units in each of Science 20 and Science 30. All expectations follow a progression from Science 10 through to Science 30, and though listed separately, are meant to be developed in conjunction with one another, within a context.

ATTITUDES

Students will be encouraged to develop:

- enthusiasm for, and a continuing interest in, science
- affective 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 and technological skills involving process skills, mathematics, and problem solving
- open-mindedness and respect for the points of view of others
- sensitivity to the living and nonliving environment
- appreciation of the roles of science and technology in our understanding of the natural world.

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 nonliving 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 that 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.

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. Students will also be expected to use teamwork, respect the points of view of others, make reasonable compromises, contribute ideas and effort, and lead when appropriate to achieve the best results. These processes involve many skills that are to be developed within the context of the program content.

Students will also be expected to be aware of the various technologies, including information technology, computer software and interfaces that can be used for collecting, organizing, analyzing and communicating data and information.

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 these new ideas, when incorporated into 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 is nonlinear and recursive. Students should be able to access skills and strategies flexibly; select and use skills, processes or technologies that are appropriate to the tasks; and monitor, modify or replace them with more effective strategies.

- 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 a problem
  - prepare required observation charts or diagrams, and carry out preliminary calculations
- Collecting and Recording
  - carry out the procedure and modify, if necessary
  - organize and correctly use apparatus and materials to collect reliable data
  - observe, gather and record data or information accurately according to safety regulations; e.g., Workplace Hazardous Materials Information System (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 effectively, using mathematical and statistical calculations, where necessary
  - express measured and calculated quantities to the appropriate number of significant digits, using SI notation 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 affect on results
  - identify assumptions, attributes, biases, claims or reasons
  - identify main ideas

- Connecting, Synthesizing and Integrating
  - predict from data or information, and determine whether or not these data verify or falsify the hypothesis and/or prediction
  - formulate further, testable hypotheses supported by the knowledge and understanding generated
  - identify further problems or issues to be investigated
  - identify alternative courses of action, experimental designs, and solutions to problems 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
  - propose solutions to a problem being 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 biases, assumptions and perspectives
  - identify limitations of the data or information, and interpretations or conclusions, as a result of the experimental/research/project/design process or method used
  - evaluate and suggest alternatives and consider improvements to the experimental technique and design, the decision-making or the problem-solving process
  - evaluate and assess ideas, information and alternatives

CONNECTIONS AMONG SCIENCE, TECHNOLOGY AND SOCIETY

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 interrelationships among science, technology and society, including:

- the central role of evidence in the accumulation of knowledge, and the ways proposed theories may be supported, modified or refuted
- the inability of science to provide complete answers to all questions
- the functioning of processes or products 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 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: A Guide to Developing Students' Research Skills*, 1990.

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.

COURSE GENERAL LEARNER EXPECTATIONS

The *course* general learner expectations are specific to each of Science 20 and Science 30 providing a bridge between the *program* general learner expectations and the specific learner expectations for each unit of study.

The attitudes expectations refer to those predispositions that are to be fostered in students. These expectations encompass attitudes toward science, the role of science and technology, and the contributions of science and technology toward society. The knowledge expectations are the major science concepts in each course. The skills expectations refer to the thinking processes and abilities associated with the practice of science, including understanding and exploring natural phenomena, and problem solving. The connections among science, technology and society expectations focus on: the processes by which scientific knowledge is developed; the interrelationships among science, technology and society; and links each course to careers, everyday life and subsequent studies of science.

Although itemized separately, the attitudes, knowledge, skills and STS connections are meant to be developed together within one or more contexts.

Science 20–30

Attitudes

Students will be encouraged to:

- appreciate the role of empirical evidence and models in science, and accept the uncertainty in explanations and interpretations of observed phenomena
- value the curiosity, openness to new ideas, creativity, perseverance and cooperative hard work required of scientists, and strive to develop these same personal characteristics
- appreciate the role of science and technology in advancing our understanding of the natural world, be open-minded and respectful of other points of view when evaluating scientific information and its applications, and appreciate that the application of science and technology by humankind can have beneficial as well as harmful effects and can cause ethical dilemmas
- show a continuing interest in science, appreciate the need for computational competence, problem-solving and process skills when doing science, and value accuracy and honesty when communicating the results of problems and investigations
- appreciate the contributions of the various science disciplines and mathematics to an understanding of the natural world, and appreciate the multidimensional nature of issues arising from the interrelationships among science, technology and society.

Science 20

Students will be able to:

Knowledge

- explain how energy and matter are transferred in physical and biogeochemical changes and cycles; and predict energy transfer and movement of matter on the Earth's surface, between components in ecosystems, and in electrochemical systems
- relate and apply, quantitatively, Newton's laws to linear and circular motion of objects and systems; and apply the principle of conservation of linear momentum to one-dimensional interactions and technologies involving motion
- describe, by citing direct and indirect evidence, how ongoing changes in Earth's crust are explained by the theory of plate tectonics, and how ongoing changes in the biosphere are explained by paleontology

- differentiate among electrolytes, non-electrolytes, acids and bases, oxidation and reduction; and identify common ions on the basis of properties, and explain the application of these properties to relevant chemical changes or processes

- apply stoichiometric methods to predict amounts of products and reactants; and calculate concentrations and volume of solutions, and mass of solute, in a variety of relevant chemical changes or processes

- name and provide structural formulas for common hydrocarbons; and classify important hydrocarbon reactions used to produce commercial and petrochemical products

<u>Skills</u>

- perform investigations and tasks of their own and others' design that have a few variables and yield direct or indirect evidence; and provide explanations based upon scientific theories and concepts

- collect, verify and organize data into tables of their own design, and graphs and diagrams of others' design, using written and symbolic forms; and describe findings or relationships, using scientific vocabulary, notation, theories and models

- analyze and interpret data that yield straight-line graphs; and use appropriate SI notation, fundamental and derived units, and formulas; and calculate slopes of, and areas under, straight-line graphs; and derive mathematical relationships among variables

- use mathematical language of ratio and proportion, simple equations, one-dimensional vector addition and subtraction, gravimetric stoichiometry, and unit analysis to solve single- and multi-step problems; and to communicate scientific relationships and concepts

<u>Connections Among Science, Technology and Society</u>

- apply cause and effect reasoning to formulate simple relationships for a given instance in which scientific evidence shapes or refutes a theory; and describe the limitations of science and technology in answering all questions and solving all problems, using appropriate and relevant examples

- describe and explain the design and function of technological solutions to practical problems, using scientific principles; and relate the ways in which science and technology advance one another, using appropriate and relevant examples

- explain for a given instance how science and technology are influenced and supported by society, and the responsibility of society, through science and technology, to protect the environment and use natural resources wisely

- identify subject-related careers and apply the knowledge and skills acquired in Science 20 to everyday life and to related and new concepts in subsequent studies of science.

Science 30

Students will be able to:

<u>Knowledge</u>

- describe the structure, function and regulatory mechanisms of the circulatory, immune and nervous systems that enable the human organism to exchange energy and matter and interact with the environment; and describe the effects of matter, such as acids, bases and organic compounds in the environment, on living systems

- investigate and describe the application of the properties of light and other electromagnetic radiation in communications, medical technologies and as indirect evidence of stellar evolution, black holes, an expanding universe and atomic structure

- explain how solar energy is stored and/or converted to other useful forms of energy in the biosphere and how mass is converted to energy; and predict, quantitatively, the heats of combustion for various fuels; and compare amounts of energy produced in nuclear, chemical and physical changes; and determine the mass-energy equivalency for hydrogen fusion

- describe field theory, compare and contrast electric, gravitational and magnetic fields; and explain the relevant applications in energy transfer technologies, telecommunications, and common electrical devices

- apply ratio, probability and the principles of heredity to predict inheritance patterns; and explain chromosome behaviour during mitosis, meiosis, and human gametogenesis and fertilization; and describe the molecular structure and function of DNA; and explain the hereditary basis of genetic diseases and disorders in humans

- use scientific concepts to differentiate acids from bases; and classify organic compounds and identify their properties based upon the functional groups present; and describe how these compounds are used to produce useful substances; and investigate the environmental issues related to their use and production

Skills

- perform and evaluate investigations and tasks of their own and others' design that have multiple variables and yield direct or indirect evidence; and provide explanations and interpretations, using scientific theories and concepts

- collect, verify and organize data into tables, graphs and diagrams of their own design, using written and symbolic forms; and describe findings or relationships and make predictions, using scientific vocabulary, notation, theories and models

- analyze, interpret and evaluate data that yield straight- and curved-lined graphs; and use appropriate SI notation, fundamental and derived units, and formulas; and calculate and analyze the slopes of, and areas under, straight-line graphs; and derive mathematical relationships among variables

- use mathematical language of ratio and proportion, equations, simple probability, gravimetric and volume stoichiometry, and unit analysis to solve single- and multi-step problems; and communicate scientific relationships and concepts

Connections Among Science, Technology and Society

- apply cause and effect reasoning to formulate relationships for a range of instances in which scientific evidence shapes or refutes a theory; and explain the limitations of science and technology in answering all questions and solving all problems, using appropriate and relevant examples

- describe and evaluate the design and function of technological solutions to practical problems, using scientific principles or theories; and relate the ways in which science and technology advance one another, using appropriate and relevant examples

- explain and evaluate for a given instance, and from a variety of given perspectives, how science and technology are influenced and supported by society; and assess the ability and responsibility of society, through science and technology, to protect the environment and use natural resources wisely

- identify subject-related careers and apply the knowledge and skills acquired in Science 30 to everyday life and to related and new concepts in post-secondary studies of science.

SPECIFIC LEARNER EXPECTATIONS

LEARNING CYCLE

The specific learner expectations consist of the knowledge, skills and attitudes that are to be addressed in Science 20–30. The use of the learning cycle allows students to progress, from:

- an introduction framing the lesson in an STS connection relevant to the lives of the learners, and makes connections between past and present learning experiences, as well as anticipates activities to focus students' thinking on the learning outcomes of the activity

TO

- the experiential exploration of new content that provides students with a common base of experiences within which they identify and develop key concepts, processes and skills

THROUGH

- a hypothesis-building phase where concepts are developed to describe a particular aspect of their experiential exploration, and opportunities are provided to communicate their conceptual understanding, or demonstrate their skills or behaviours

TO

- an elaboration phase that extends understanding of key concepts and allows further opportunities to practise desired skills and problem-solving strategies

TO

- an application phase where the hypotheses, vocabulary and patterns previously developed are applied to new situations and related to key concepts and principles of science

TO

- a final evaluation of the significance of the new learning in an STS context to assess their understanding and abilities, and provide opportunities for evaluation of student progress toward achieving the curriculum standards.

In Science 20–30, students examine phenomena in a variety of topics to show the relationships among all the sciences. Wherever possible, examples should be framed in the context of the learners' own experiences to enable them to make the connections between scientific knowledge and the society around them, the technology that societies have developed, and the nature of science itself.

PROGRAM OVERVIEW

The Science 20–30 program emphasizes the science themes: *change, diversity, energy, equilibrium, matter* and *systems* as they relate to science. These themes provide a means of showing the connections among the units of study in both courses of the program and among all the science disciplines, and provide a framework for students to learn how individual sections of the program relate to the big ideas of science.

In addition to developing a solid understanding of fundamental science concepts and principles, Science 20–30 has the goal of educating students about the nature of science and technology, and the interaction between science and technology. Students must be aware of the tremendous impact of science and associated technology on society, but at the same time, they must be aware of the roles and limitations of the sciences and technology in problem solving in a societal context.

SCIENCE 20

Change is the theme common to all the units in Science 20. Analysis of *change* is essential for understanding what is happening and for predicting what will happen; and control of *change* is essential for the design of technological *systems*. *Diverse* forms of *matter*, *energy*, life forms and climatic conditions characterize the *systems* found on Earth. The principles of conservation of mass, *energy* and momentum and the concept of *equilibrium* help to predict and explain the *changes* that occur in a closed *system*.

The major concepts allow connections to be drawn among the four units of the course and among all eight units in the two courses in the program.

Science 20 consists of four units of study:

Unit 1: The Changing Earth
Unit 2: Changes in Living Systems
Unit 3: Chemical Changes
Unit 4: Changes in Motion.

Each unit in Science 20 uses a different context to investigate the processes by which natural entities and *systems* are modified over time, and to identify common patterns to *change*. In Unit 1, there is an examination of the evidence indicating that *diverse* climatic conditions and life forms have existed on Earth. Geologic evidence is used to study the patterns of *change* that have occurred in the biosphere over the entire span of Earth's history. Unit 2 examines ongoing *change* in the biosphere, focusing on the flow of *matter* through biogeochemical cycles and the flow of *energy* through the trophic levels of an *ecosystem*. In Unit 3, the principles of chemical *change* to *matter* and the role of *energy* in these *changes* are investigated and their application in the chemical industry is examined. Unit 4 investigates the relationship between force and the motion of objects, using Newton's laws of conservation of momentum to explain and predict *changes* in motion to *systems* and the attainment of *equilibrium*.

SCIENCE 30

The major science themes developed in this course are *energy* and *systems*. Thinking of any collection of objects, cells or processes as a *system* draws attention to how the parts of the *system* interact with one another as they undergo *change*. The components of a *system* influence each other not only by transfer of *energy* and *matter* but also by transfer of information. The *diverse* forms of *energy* and *matter* and the maintenance of *equilibrium* in the global *ecosystem* undergoing *change* are other themes developed in Science 30.

The major concepts allow connections to be made among the four units of the course and among all eight units in two courses in the program.

Science 30 consists of four units of study:

Unit 1: Living Systems Respond to Their Environment
Unit 2: Chemistry in the Environment
Unit 3: Electromagnetic Energy
Unit 4: Energy and the Environment.

Science 30 expands upon the concepts and skills introduced in Science 10 and Science 20. Making *changes* in one part of a *system* can cause profound *changes* in other parts of the *system*, as is illustrated in different contexts in each unit of Science 30. Unit 1 uses the human organism to illustrate some of the mechanisms that enable living *systems* to respond to their environment while maintaining internal *equilibrium*. Unit 2 continues the theme of *changes* to *matter* and introduces environmental chemistry, focusing on the impact of acids, bases and organic compounds on *ecosystems*. In Unit 3, the *diverse* forms of electromagnetic *energy* are studied, and their uses in communication and scientific research are addressed. Unit 4 examines the range of renewable and nonrenewable *energy* sources available for commercial use and considers the impact of their use on the global *ecosystem*.

UNIT 3
CHEMICAL CHANGES

OVERVIEW

Science Themes: *Change, Energy* and *Matter*

In Unit 3, students investigate the *changes* that occur in *matter* during chemical reactions, including oxidation–reduction and organic reactions and add to their knowledge of the relationship between chemical *change* and *energy*. They are introduced to the quantitative aspects of chemical *change* within the context of some of the chemical reactions that are used in Alberta chemical industries.

This unit builds upon Science 8, Unit 1: Solutions and Substances; and Science 10, Unit 3: Energy and Matter in Chemical Change, and provides a foundation for the further study of chemistry.

The four **major concepts** developed in this unit are:

- aqueous solutions provide a convenient medium for chemical *changes*
- balanced chemical equations show the quantitative relationships between the reactants and products involved in chemical reactions
- oxidation and reduction reactions are an example of chemical *change* involving *energy*
- hydrocarbons are the starting substances for many organic compounds.

In this unit, *students will develop* an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- initiating and planning
- collecting and recording
- organizing and communicating
- analyzing data from investigations of chemical *change*.

The STS connections in this unit illustrate:

- the functioning of products or processes based on scientific principles
- the use of technology to solve practical problems
- 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.

ATTITUDES

Students will be encouraged to:

- develop a questioning attitude and a desire to understand more about *matter* and its *changes*
- develop an awareness of the importance of water as a medium for chemical reactions
- appreciate that observations are the foundation for generalizations and explanations about chemical *change*
- develop an appreciation for the usefulness and importance of stoichiometric methods in science and in industry
- appreciate that science and technology provide many useful products
- appreciate the importance of careful laboratory techniques and precise calculations for obtaining accurate results
- value the need for safe handling, storage and disposal of chemicals, and the Workplace Hazardous Materials Information System (WHMIS) symbols.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. **Aqueous solutions provide a convenient medium for chemical *changes*.**	• **aqueous solutions provide a convenient medium for chemical changes, by extending from Science 8, Unit 1, the meaning of the terms solute, solvent, solution, dissolving and solubility, and by:** • **providing examples from living and nonliving systems of how dissolving substances in water is often a prerequisite for chemical change; e.g., venous transport of carbon dioxide, acid rain** • **differentiating on the basis of properties among electrolytes, nonelectrolytes, acids and bases** • **relating the properties of a solution to the nature of the dissolved chemical; i.e., conductivity, acidic, basic and neutral** • **using chemical names and formulas for dissolved substances, acids and bases** • **calculating the concentration of solutions in a variety of ways, including moles per litre, and calculating mass or volume when the concentration is known; e.g., per cent by volume, parts per million (ppm)** • **determining the concentration of diluted solutions and the quantities of solution and solvent to use when diluting** • **describing dynamic equilibrium in a saturated solution in terms of equal rates of dissolving and crystallization.**

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding dissolving, aqueous solutions and concentration; and by investigating the properties of solutions, preparing solutions of specific concentration and identifying ions in solution, within the context of:
• investigating, qualitatively, the properties of solutions and in the laboratory • preparing solutions of specified concentrations, using a balance and volumetric glassware • determining, experimentally, the identity of some common ions, using simple qualitative tests, such as colour and solubility • identifying Workplace Hazardous Materials Information System (WHMIS) symbols.	• relating the properties of electrolytes, nonelectrolytes, acids and bases and reactions in aqueous solution to solutions and processes in everyday life **OR** • comparing the ways in which concentrations of solutions are expressed in the chemistry laboratory (moles per litre), in industry (a variety of ways), in household products (per cent by volume) and in environmental studies (parts per million), then evaluating the importance of concentration in relation to biomagnification and risk management **OR** • describing the processes and scientific principles involved in water treatment plants **OR** • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
2. **Balanced chemical equations show the quantitative relationships between the reactants and products involved in chemical reactions.**	• **the mole ratios in balanced chemical reaction equations provide quantitative information about the substances involved, by recalling from Science 10, Unit 3, how to balance chemical equations, and by:** • **predicting, using stoichiometry, the quantities of products and reactants involved in chemical reactions, given the reaction equation and the limiting reagent.**

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	***Students should be able to demonstrate the interrelationships among science, technology and society, by:***
	• understanding the quantitative relationships in a balanced chemical equation; and by performing stoichiometric experiments and calculations, within the context of:
• checking the results of mathematical calculations, using unit analysis • performing simple experiments to illustrate the validity of the assumptions contained in stoichiometric methods, given the reaction equation and the limiting reagent • evaluating the design of stoichiometric experiments.	• relating stoichiometric methods to chemical processes, such as the production of fertilizers, metal extraction and burning fossil fuels OR • relating stoichiometric methods to such chemical processes as cooking, cleaning and gardening OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
3. **Oxidation and reduction reactions are an example of chemical *change* involving *energy*.**	• **many chemical reactions involve oxidation and reduction, by:** • **determining the placement of metals in the activity series** • **defining oxidation as a loss of electrons and reduction as a gain of electrons** • **applying the principles of oxidation and reduction to describe the operation of galvanic and electrolytic cells.**

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding the activity series and oxidation–reduction; and by constructing, observing and describing electrolytic and electrochemical cells, within the context of:
• constructing galvanic and electrolytic cells; and observing and describing the functioning of these cells in terms of the loss and gain of energy and electrons.	• identifying examples and making analogies among oxidation–reduction occurring in everyday processes; e.g., corrosion, combustion, photosynthesis, respiration OR • illustrating applications of oxidation–reduction to solve practical problems; e.g., batteries, metal extraction, cathodic protection, galvanizing, electroplating OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
4. Hydrocarbons are the starting substances for many organic compounds.	• hydrocarbons are the basis for many common organic compounds, by: • identifying the general characteristics of hydrocarbons; e.g., melting point, boiling point, solubility • providing International Union of Pure and Applied Chemistry (IUPAC) names and structural formulas for simple, branched and noncyclic hydrocarbons in the homologous series of alkanes, alkenes and alkynes, involving up to ten carbon atoms • classifying the important reactions of hydrocarbons, such as combustion, addition, substitution and polymerization • identifying hydrocarbons as a source of energy in fossil fuels • describing and naming some important petrochemicals produced from hydrocarbons; e.g., polyethene, polystyrene, polyvinyl chloride, ethylene glycol.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding the general characteristics, sources, structures, nomenclature and reactions of hydrocarbons and some of the petrochemicals produced from them; and by investigating the physical and chemical properties of hydrocarbons, within the context of:
• investigating the physical and chemical properties of hydrocarbons, using safe substances and procedures • investigating the physical and chemical properties of some common plastics • using commercial kits to prepare polymers.	• providing examples of hydrocarbons and petrochemicals used on a daily basis in terms of their impact on quality of life OR • explaining the processes, in terms of scientific principles, of fractional distillation and catalytic cracking, and reforming and polymerization, as applied to the production of petroleum products OR • explaining the processes, in terms of scientific principles, of hydrogenation and halogenation to produce commercial products OR • describing the ethylene industry in Alberta, in terms of the scientific and technological principles applied OR • any other relevant context.

UNIT 2
CHEMISTRY IN THE ENVIRONMENT

OVERVIEW

Science Themes: *Change, Matter* and *Systems*

In Unit 2, students examine the role of chemical *changes* to *matter* in environmental studies, with a focus on the properties and reactions of acids, bases and selected organic compounds. The important effects of synthetic organic compounds and acids and bases on living and nonliving *systems* are explored.

This unit builds upon Science 10, Unit 3: Energy and Matter in Chemical Change; and Science 20, Unit 3: Chemical Changes, and provides a foundation for the further study of chemistry.

The three **major concepts** developed in this unit are:

- acids and bases affect the chemistry of aqueous *systems* and have important environmental effects
- chemistry is an essential component of environmental studies
- organic compounds can have environmental effects.

In this unit, *students will develop* an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- analyzing data from the study of chemistry in the environment
- connecting, synthesizing and integrating data from the study of chemistry in the environment
- evaluating the process or outcomes from the study of chemistry in the environment.

The **STS connections** in this unit illustrate:

- the inability of science to provide complete answers to all questions
- the functioning of products or processes based on scientific principles
- the influence of the needs, interests and financial support of society on scientific and technological research.

ATTITUDES

Students will be encouraged to:

- value the role of precise observation and experimentation in learning about the chemistry of acids, bases and organic compounds
- value the need for safe handling, storage and disposal of chemicals and materials
- recognize the limits of current scientific knowledge of complex environmental problems
- demonstrate intellectual honesty, open-mindedness and objectivity when assessing environmental effects caused by chemical *change*
- appreciate the benefits to society of acids, bases and synthetic organic compounds
- recognize that the application of technology by human societies can have beneficial and harmful effects on biological *systems*
- value the role of chemistry in monitoring the environment and in understanding and working to resolve environmental problems
- develop an awareness of the need for evaluating environmental issues from a variety of perspectives.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. Acids and bases affect the chemistry of aqueous *systems* and have important environmental effects.	• acids and bases affect the chemistry of aqueous systems and have important environmental effects, by extending from Science 20, Unit 3, a knowledge of solutions, and by: • defining acids and bases in terms of the Brønsted–Lowry principle • outlining the procedures and regulations governing the safe handling, storage and disposal of acidic and caustic chemicals • describing the relationship between pH and hydronium ion concentration; i.e., a change of 1 in pH is equivalent to a ten-fold change in the hydronium ion concentration • calculating pH from hydronium ion concentration, and hydronium ion concentration from pH • differentiating between strength and concentration, using examples of organic and inorganic acids • explaining how buffers maintain a relatively constant pH when small amounts of acid or base are added to an aqueous system • explaining the importance of maintaining a relatively constant pH in living systems • explaining what is meant by the buffering capacity of soil or bedrock • explaining the colour changes of indicators in terms of the Brønsted–Lowry principle • determining the concentration of a strong acid or a strong base, using stoichiometry and titration data • describing changes to the living and nonliving environment caused by acid deposition, such as accelerated corrosion, metal leaching from bedrock and the physiological effects on living organisms.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	***Students should be able to demonstrate the interrelationships among science, technology and society, by:***
	• **understanding the effects of acids and bases on aqueous systems and the environment, defining acids and bases, pH, strength, concentration, buffers and indicators; describing the sources, causes and effects on the environment of acid rain; and by using tests to differentiate solutions, using titration to determine concentration, carrying out investigations into acid rain and buffers, and evaluating technology for reducing acid rain, within the context of:**
• measuring the pH of some common substances, using a pH meter and/or pH paper and indicators • differentiating among acids, bases, neutral ionic and neutral molecular compounds, using diagnostic tests • differentiating between strong and weak acids and bases, using diagnostic tests • carrying out and evaluating a titration experiment to determine the concentration of an acid or base solution • carrying out and evaluating an experiment to investigate buffer action.	• describing, in general terms, the commercial processes used to produce acids and bases; e.g., hydrochloric acid and sodium hydroxide; and providing examples of how these products are put to use **OR** • examining, from a variety of perspectives, the issue of transporting acidic and caustic substances through populated areas; and describing ways to solve problems at an accidental acid or base spill, using dilution and neutralization, in order to protect the environment from damage **OR** • explaining, in terms of the scientific principles involved, how the pH of body fluids is maintained at a constant level when various foods are digested and absorbed **OR** • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
2. Chemistry is an essential component of environmental studies.	• chemistry is an essential component of environmental studies, by: • outlining the chemical reactions that lead to the production of air pollutants, such as sulphur dioxide, nitrogen oxides and photochemical smog • writing reaction equations to represent the production and treatment of acid deposition components • outlining, briefly, the evidence indicating that chlorofluorocarbons (CFCs) are involved in the depletion of the ozone layer • indicating the source of water pollutants, such as phosphates, hydrocarbons, organic matter, heavy metals, dioxins and furans • explaining the sampling protocols and analysis techniques used in monitoring water quality, such as taking samples from several different depths and points on a lake or river, storing and transporting samples in appropriate containers, maximum storage time before testing • describing, briefly, some methods used to monitor water quality, such as tests for biochemical oxygen demand (BOD), chemical oxygen demand (COD), pH, turbidity, heavy metals and organic compounds in water.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding the chemical processes that lead to the production of common air and water pollutants and depletion of the ozone layer; and explaining the sampling protocols, analysis techniques and methods used to monitor water quality; and by collecting and testing water samples, and designing an experiment to investigate seasonal variations in the composition of water in the community, within the context of:
• collecting and testing samples of water, using standard procedures • evaluating sources of error in water quality testing • testing and evaluating a method for purifying water • identifying variables and controls in environmental studies • designing an experiment that would investigate seasonal variations in the composition of water in the community • illustrating, with the use of maps, the role of weather in the distribution patterns of acid deposition • designing, carrying out and evaluating an investigation of some of the environmental effects of acid rain.	• investigating sources of water pollution in the community or local area; and establishing the central role of experimental evidence in the accumulation of knowledge regarding the pollution and its sources **OR** • describing the chemical principles involved in the technologies designed to reduce pollution, and evaluate the effectiveness of these technologies, given the limitations of scientific knowledge and technology to solve environmental problems **OR** • identifying and explaining the human activities that contribute to acid deposition in terms of chemical principles and analyzing the relationships among societal needs, interests and financial support for scientific research into acid deposition, and the need for technologies to reduce acid-forming emissions **OR** • analyzing, from a variety of perspectives, some methods being used to reduce the incidence and effects of acid rain, such as reducing the sulfur content of coal, collecting sulfur dioxide emissions to make sulfuric acid, and liming lakes; and explaining what is meant by a "technological fix" attitude and the limitations of scientific knowledge and technology in reducing the effects of acid rain **OR** • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
3. Organic compounds can have environmental effects.	• organic compounds can impact the environment, by recalling from Science 20, Unit 3, the source of petrochemicals, and by: • recognizing halogenated hydrocarbons, alcohols, aldehydes, ketones, carboxylic acids and esters from the functional groups in their structure • providing the names and formulas of members of the above categories of compounds containing up to three carbon atoms, and describing their common uses • describing, in general terms, the chemical and physical processes involved in converting natural wood fibre into paper, and the environmental concerns associated with the pulp and paper industry • identifying and describing the environmental issues related to the byproducts, particularly chlorinated compounds, such as dioxins and furans, of particular processes involving organic compounds, in terms of the need to protect the environment for future generations • describing the biomagnification of an organic compound, such as a pesticide, as it moves through an ecosystem, identifying harmful effects that could occur.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	***Students should be able to demonstrate the interrelationships among science, technology and society, by:***
	• **understanding organic compounds and their environmental effects by identifying the functional groups, names, formulas and uses of common examples; describing natural and synthetic polymers and pesticides and their effect on living systems and the ecosystem; and by investigating the properties of and preparing examples of organic compounds, within the context of:**
• investigating the properties; e.g., state, solubility, odour, melting point, boiling point, of representative alcohols, aldehydes, ketones, organic acids and esters • investigating, through experimentation or research, the action of a pesticide; i.e., target specificity, accumulation in the environment, biodegradability, effectiveness, development of resistance • preparing a synthetic organic compound, and investigating its properties; e.g., an alcohol, an ester, a soap.	• explaining, in general terms, the technological processes and scientific principles applied to synthesize many useful compounds from fossil fuels OR • identifying and describing, in an objective and open-minded way, the environmental issues related to the production and use of petrochemicals; and assessing the risks and benefits associated with the use of petrochemicals, such as pesticides; and evaluating alternatives to petrochemicals in light of the need to protect the environment and use natural resources judiciously OR • researching current technologies related to finding alternative methods of producing cellulose/paper OR • describing positive and negative effects of current and past developments in synthetic organic chemistry, and citing examples of the influence of societal needs, interests and financial support for scientific and technological research in this area OR • any other relevant context.

UNIT 4
ENERGY AND THE ENVIRONMENT

OVERVIEW

Science Themes: *Energy* and *Systems*

In Unit 4, students investigate the potential of a wide range of renewable and nonrenewable *energy* sources to provide for global *energy* needs. In considering the merits of alternative *energy* sources, the major guiding principle is that the global demand for *energy* must be reconciled with the need for a viable global *ecosystem*.

This unit builds on the concepts of *energy* and *systems* developed in Science 10, Unit 1: Energy from the Sun, Unit 4: Change and Energy; and in Science 20, Unit 1: The Changing Earth, Unit 2: Changes in Living Systems, and Unit 3: Chemical Changes.

The four **major concepts** developed in this unit are:

- the global demand for *energy* must be reconciled with the need to maintain a viable biosphere
- the Sun is Earth's main source of *energy*
- mass is converted to *energy* in nuclear reactions
- the interaction of the gravitational fields of the Sun, Moon and Earth is the source of tidal *energy*.

In this unit, ***students will develop*** an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- organizing and communicating
- analyzing
- connecting, synthesizing and integrating data from investigations of *energy* and the environment
- evaluating the process or outcomes from investigations of *energy* and the environment.

The STS connections in this unit illustrate:

- the functioning of products or processes based on scientific principles
- the use of technology to solve practical problems
- 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.

ATTITUDES

Students will be encouraged to:

- appreciate the unity of science through the application of principles from biology, chemistry, physics and Earth sciences to the study of *energy* and the environment
- appreciate the need to reconcile the global demand for *energy* with the need to maintain a viable global *ecosystem*
- be concerned about the efficient use and conservation of *energy* resources locally and globally
- appreciate that issues related to *energy* and the environment involve the interrelationships among science, technology and society
- be open-minded when considering the merits of alternative *energy* sources
- consider all the evidence available when evaluating alternative *energy* sources
- develop a questioning attitude about the environmental impact of current and future *energy* sources.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. The global demand for *energy* must be reconciled with the need to maintain a viable biosphere.	• global energy demands must be reconciled with the need to maintain a viable biosphere, by extending from Science 10, Unit 4, the knowledge that useful energy diminishes during any energy transformation, the definition for efficiency, and by: • describing the exponential growth of global energy consumption • explaining the importance of more efficient energy use in a global energy strategy • explaining the term "sustainable development" • describing the environmental impact of developing various energy sources, such as offshore oil, wind power, nuclear fission • identifying renewable energy sources that have the potential to provide a greater share of global energy needs.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	***Students should be able to demonstrate the interrelationships among science, technology and society, by:***
	• **understanding and explaining that the growth of global energy demands must be reconciled with the need to maintain a viable biosphere in terms of efficient energy use, renewable energy sources, sustainable development and environmental impact; and by analyzing and interpreting graphs of energy consumption, and by carrying out investigations and calculations relating to the efficient use of energy, within the context of:**
• interpreting graphs of current and projected energy consumption • analyzing energy consumption by various sectors; e.g., metallurgy, petrochemical, pulp and paper, transportation • designing and constructing a hot water heater, and calculating its efficiency • comparing linear and exponential growth, using relevant examples and graphing.	• evaluating the consequences of Canada's per capita energy consumption on the biosphere; and identifying and evaluating ways, including recent technology, to use energy more efficiently in the home, large buildings or the community, in order to protect the biosphere, thereby ensuring quality of life for future generations OR • assessing the environmental impact of a primary local energy source, such as hydroelectric or coal-burning power, and their effect on quality of life for future generations OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
2. The Sun is Earth's main source of *energy*.	• the Sun is Earth's main source of energy, by extending from Science 10, Unit 1, a knowledge of the Sun's role in photosynthesis and weather, and by: • indicating what proportion of the solar radiation striking Earth creates the wind, powers the water cycle and initiates photosynthesis • describing the conversion of radiant solar energy into thermal and electrical energy • explaining how wind and water power originate with the Sun • explaining how the energy stored in fossil fuels originated in the Sun • comparing cellular respiration to the combustion of fuels.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• **understanding and explaining how solar radiation initiates photosynthesis, creates fossil fuels, drives wind and water power; and how radiant solar energy is converted to other forms; and by investigating the combustion of fuels and cellular respiration; and by designing, carrying out and evaluating experiments to compare various ways of converting energy, within the context of:**
• drawing analogies between the Sun heating the Earth as a closed system, and heating a home as a closed system	• comparing and contrasting ancient and modern technologies for directly harnessing solar energy, in terms of scientific principles
• comparing, graphically, the commercial potential of various renewable energy resources, such as solar power, wind power, hydroelectric power and biomass	OR
• designing, carrying out and evaluating an experiment to investigate the factors influencing the output of an energy conversion device; e.g., a solar collector, a photovoltaic cell, a fossil fuel burner	• analyzing the functioning of "active" and "passive" solar heating technologies in terms of scientific principles, design features and constraints used in constructing solar heated buildings; and evaluating ways in which solar heating can be used to reduce heating costs
• predicting heats of combustion for different fuels, using heats of formation and Hess's law $\Delta H_f^\circ = \Sigma \Delta H_f^\circ$ (products) $- \Sigma \Delta H_f^\circ$ (reactants).	OR
	• describing the functioning of new technology for harnessing wind, water and biomass energy
	OR
	• describing 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; e.g., the commercial development of renewable and nonrenewable energy resources
	OR
	• any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
3. Mass is converted to *energy* in nuclear reactions.	• mass is converted to energy in nuclear reactions, by extending from Science 30, Unit 3, a knowledge of the nuclear processes occurring in the Sun, and by: • explaining the difference between fission and fusion reactions • writing simple equations to represent nuclear reactions and to show the conservation of nucleons • describing, in general terms, the operation of a fission reactor, such as the Canadian Deuterium Uranium Reactor (CANDU) • describing the current state of fusion research • comparing, quantitatively, the relative amounts of energy produced by nuclear, chemical and phase changes.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	***Students should be able to demonstrate the interrelationships among science, technology and society, by:***
	• understanding and explaining the difference between fission and fusion reactions, describing various places they occur, and comparing nuclear, chemical and phase changes; and by analyzing technologies for harnessing nuclear and geothermal energy, within the context of:
• observing evidence of radioactive decay in a cloud chamber or on a video • applying, in quantitative terms, mass/energy equivalency to fission and fusion reactions; i.e., $E = mc^2$ • comparing conventional and nuclear power stations • representing, schematically, the energy input, conversion and output in a nuclear reactor • doing a risk/benefit analysis from a variety of perspectives of one of the following: – nuclear power station – geothermal power station – fossil fuel power station – hydroelectric power station – wind farm.	• debating whether or not the needs and interests of society are being served by the expenditure of public money on fusion research OR • analyzing the risks and benefits of nuclear energy in terms of meeting societal needs, protecting the environment and using natural resources judiciously OR • explaining, in terms of the scientific principles involved, the relationship between nuclear energy and hot spring resorts in the Canadian Rockies OR • describing, in general terms, the functioning of technologies designed to harness geothermal energy OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
4. **The interaction of the gravitational fields of the Sun, Moon and Earth is the source of tidal *energy*.**	• **the interaction of the gravitational fields of the Sun, Moon and Earth is the source of tidal energy, by:** • **explaining the source of tides in terms of Newton's law of universal gravitation and the relative motions of the Sun, Moon and Earth** • **describing the energy transformations involved in converting tidal energy into electrical energy.**

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• understanding and explaining that the source of tidal energy is the interaction of the gravitational fields of the Sun, Moon and Earth, describing the transformation of tidal energy to electrical energy; and by comparing and contrasting tidal and hydroelectric power, within the context of:
• researching the potential of tidal power, using library resources, newspaper articles or the Internet • comparing tidal power with hydroelectric power.	• describing the functioning of the technology required to harness the Bay of Fundy tides; and analyzing the risks and benefits of constructing tidal power stations in terms of meeting societal needs, protecting the environment and using natural resources judiciously OR • any other relevant context.

CHEMISTRY 20–30

A. PROGRAM OVERVIEW

RATIONALE AND PHILOSOPHY

Chemistry is the study of matter and its changes. Through the study of chemistry, learners are given an opportunity to explore and understand the natural world and to become aware of the profound influence of chemistry in their lives. Learning is facilitated by relating the study of chemistry to what the learners already know, deem personally useful and consider relevant. Learning proceeds best when it originates from a base of concrete experiences presenting an authentic view of science in the context of chemistry. In Chemistry 20–30, students learn chemistry in relevant contexts and engage in meaningful activities. This facilitates the transfer of knowledge to new contexts. Students are encouraged to participate in lifelong learning about chemistry and to appreciate it as a scientific endeavour with practical impact on their own lives and on society as a whole.

Chemistry, as with all sciences, is an experimental discipline requiring creativity and imagination. Methods of inquiry characterize its study. In Chemistry 20–30, 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 their critical thinking skills. Through experimentation, and problem-solving activities that include the integration of technology and independent study, students develop an understanding of the processes by which scientific knowledge evolves.

The Chemistry 20–30 program places students at the centre. Students are active learners and will assume increased responsibility for their learning as they work through the program. A thorough study of chemistry is required to give students an understanding that encourages them to make appropriate applications of scientific concepts to their daily lives and prepares them for future studies in chemistry. Students are expected to participate actively in their own learning. An emphasis on the key concepts and principles of chemistry provides students with a more unified view of the sciences and a greater awareness of the connections among them.

These science learnings will take varying amounts of time to acquire, depending on the individual learning styles and abilities of students. While each course is designed for approximately 125 hours, instructional time can be modified to meet the individual needs of students. Some students will require more than 125 hours, while others will require less.

GOALS

The major goals of the Chemistry 20–30 program are:

- to develop in students an understanding of the 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 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.

Chemistry 20–30 is an academic program that helps students better understand and apply fundamental concepts and skills. The focus is on helping students understand the chemistry 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 chemistry 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. LEARNER EXPECTATIONS

GENERAL LEARNER EXPECTATIONS

The general learner expectations outline the many facets of scientific awareness and serve as the foundation for the specific learner expectations covered in section C. The general learner expectations are developed in two categories: *program* expectations and *course* expectations.

PROGRAM GENERAL LEARNER EXPECTATIONS

The *program* general learner expectations are broad statements of science attitudes, knowledge, skills and science, technology and society (STS) connections that students are expected to achieve in all of the senior high school science programs. These *program* general learner expectations are further refined through the *course* general learner expectations and then developed in specific detail through the study of individual units in each of Chemistry 20 and Chemistry 30. All expectations follow a progression from Science 10 through to Chemistry 30, and though listed separately, are meant to be developed in conjunction with one another, within a context.

ATTITUDES

Students will be encouraged to develop:

- enthusiasm for, and a continuing interest in, science
- affective 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 and technological skills involving process skills, mathematics, and problem solving
- open-mindedness and respect for the points of view of others
- sensitivity to the living and nonliving environment
- appreciation of the roles of science and technology in our understanding of the natural world.

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 nonliving 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 that 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.

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. Students will also be expected to use teamwork, respect the points of view of others, make reasonable compromises, contribute ideas and effort, and lead when appropriate to achieve the best results. These processes involve many skills that are to be developed within the context of the program content.

Students will also be expected to be aware of the various technologies, including information technology, computer software and interfaces that can be used for collecting, organizing, analyzing and communicating data and information.

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 these new ideas, when incorporated into 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 is nonlinear and recursive. Students should be able to access skills and strategies flexibly; select and use skills, processes or technologies that are appropriate to the tasks; and monitor, modify or replace them with more effective strategies.

- 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 a problem
  - prepare required observation charts or diagrams, and carry out preliminary calculations
- Collecting and Recording
  - carry out the procedure and modify, if necessary
  - organize and correctly use apparatus and materials to collect reliable data
  - observe, gather and record data or information accurately according to safety regulations; e.g., Workplace Hazardous Materials Information System (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 effectively, using mathematical and statistical calculations, where necessary
  - express measured and calculated quantities to the appropriate number of significant digits, using SI notation 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 affect on results

- identify assumptions, attributes, biases, claims or reasons
- identify main ideas

- Connecting, Synthesizing and Integrating
  - predict from data or information, and determine whether or not these data verify or falsify the hypothesis and/or prediction
  - formulate further, testable hypotheses supported by the knowledge and understanding generated
  - identify further problems or issues to be investigated
  - identify alternative courses of action, experimental designs, and solutions to problems 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
  - propose solutions to a problem being 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 biases, assumptions and perspectives
  - identify limitations of the data or information, and interpretations or conclusions, as a result of the experimental/research/project/design process or method used
  - evaluate and suggest alternatives and consider improvements to the experimental technique and design, the decision-making or the problem-solving process
  - evaluate and assess ideas, information and alternatives

CONNECTIONS AMONG SCIENCE, TECHNOLOGY AND SOCIETY

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 interrelationships among science, technology and society, including:

- the central role of evidence in the accumulation of knowledge, and the ways proposed theories may be supported, modified or refuted
- the inability of science to provide complete answers to all questions
- the functioning of processes or products 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 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: A Guide to Developing Students' Research Skills*, 1990.

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.

COURSE GENERAL LEARNER EXPECTATIONS

The *course* general learner expectations are specific to each of Chemistry 20 and Chemistry 30 providing a bridge between the *program* general learner expectations and the specific learner expectations for each unit of study.

The attitudes expectations refer to those predispositions that are to be fostered in students. These expectations encompass attitudes toward science, the role of science and technology, and the contributions of science and technology toward society. The knowledge expectations are the major chemistry concepts in each course. The skills expectations refer to the thinking processes and abilities associated with the practice of science, including understanding and exploring natural phenomena, and problem solving. The connections among science, technology and society expectations focus on: the processes by which scientific knowledge is developed; the interrelationships among science, technology and society; and links each course to careers, everyday life and subsequent studies of chemistry.

Although itemized separately, the attitudes, knowledge, skills and STS connections are meant to be developed together within one or more contexts.

Chemistry 20–30

Attitudes

Students will be encouraged to:

- appreciate the role of empirical evidence and models in science, and accept the uncertainty in explanations and interpretations of observed phenomena
- value the curiosity, openness to new ideas, creativity, perseverance and cooperative hard work required of scientists, and strive to develop these same personal characteristics
- appreciate the role of science and technology in advancing our understanding of the natural world, be open-minded and respectful of other points of view when evaluating scientific information and its applications, and appreciate that the application of science and technology by humankind can have beneficial as well as harmful effects and can cause ethical dilemmas
- show a continuing interest in science, appreciate the need for computational competence, problem-solving and process skills when doing science, and value accuracy and honesty when communicating the results of problems and investigations
- value the need for safe handling, storing and disposing of chemicals and materials with care for the environment.

Chemistry 20

Students will be able to:

Knowledge

- apply the principles of energy and matter conservation to chemical systems undergoing change; and use direct evidence and generalizations to predict the outcomes of chemical change; and relate chemical change principles to a variety of reaction applications
- analyze physical, chemical and biological systems in terms of energy and matter forms, transfers, movement and conservation
- explain the interrelationship between energy and chemical changes to matter and how energy is either released or absorbed as chemical bonds are rearranged and new substances are formed; and describe the practical applications of exothermic and endothermic changes

- explain chemical changes to matter; and write balanced chemical equations to describe transformations and analyze them, quantitatively and qualitatively, to make predictions about the products formed or reactants consumed; and apply this knowledge to stoichiometric calculations in a variety of everyday and industrial situations

- describe solution systems, including acids, bases and gases, quantitatively and qualitatively, and relate their properties to their uses

- describe the diverse forms of matter, using models to illustrate bonding and structure, and using theories to explain the properties and behaviour of a variety of elements and organic and inorganic compounds and solutions, including acids, bases and gases

Skills

- perform investigations and tasks of their own and others' design that have a few variables and yield direct or indirect evidence; and provide explanations based upon scientific theories and concepts

- collect, verify and organize data into tables of their own design, and graphs and diagrams of others' design, using written and symbolic forms; and describe findings or relationships, using scientific vocabulary, notation, theories and models

- analyze and interpret data that yield straight- and curved-line graphs; and use appropriate SI notation, fundamental and derived units, and formulas; and derive from graphs mathematical relationships among variables

- use mathematical language of ratio and proportion, numerical and algebraic methods, gravimetric and solution stoichiometry and unit analysis to solve single- and multi-step problems; and to communicate scientific relationships and concepts

Connections Among Science, Technology and Society

- apply cause and effect reasoning to formulate simple relationships for a given instance in which scientific evidence shapes or refutes a theory; and describe the limitations of science and technology in answering all questions and solving all problems, using appropriate and relevant examples

- describe and explain the design and function of technological solutions to practical problems, using scientific principles; and relate the ways in which chemistry and technology advance one another, using appropriate and relevant examples

- explain for a given instance how science and technology are influenced and supported by society, and the responsibility of society, through chemistry and technology, to protect the environment and use natural resources wisely

- identify subject-related careers and apply the knowledge and skills acquired in Chemistry 20 to everyday life and to related and new concepts in subsequent studies of chemistry.

Chemistry 30

Students will be able to:

Knowledge

- apply the principles of energy and matter conservation to chemical systems undergoing change; and use direct and indirect evidence and theoretical knowledge to predict the outcomes of chemical change; and relate chemical change principles to a broad range of reaction applications

- analyze and evaluate biological, chemical and physical systems in terms of energy and matter forms, transfers, movement and conservation

- explain the interrelationship between energy and physical, chemical and nuclear changes to matter by describing how the rearrangement of bonds results in the release or absorption of energy; and evaluate society's production and use of energy from fossil fuels and nuclear fission

- analyze and explain, quantitatively and qualitatively, the transfer of electrons, and the energy and matter transformations that take place in electrochemical systems; and write balanced oxidation–reduction equations; and describe applications of oxidation–reduction reactions in electrochemical and electrolytic cells

- describe chemical equilibrium systems for acids, bases and gases, quantitatively and qualitatively, and describe some applications

- explain the Brønsted–Lowry concept of acids and bases; and, quantitatively and qualitatively, describe acid and base solutions in a variety of ways; and write and analyze reaction equations; and perform calculations and interpretations from titration data

<u>Skills</u>

- perform and evaluate investigations and tasks of their own and others' design that have multiple variables and yield direct or indirect evidence; and provide explanations and interpretations, using scientific theories and concepts

- collect, verify and organize data into tables, graphs and diagrams of their own design, using written and symbolic forms; and describe findings or relationships and make predictions, using scientific vocabulary, notation, theories and models

- analyze, interpret and evaluate data that yield straight- and curved-line graphs; and use appropriate SI notation, fundamental and derived units, and formulas; and derive from graphs mathematical relationships among variables

- use mathematical language of ratio and proportion, numerical and algebraic methods, and unit analysis to solve multi-step, nonroutine problems; and communicate scientific relationships and concepts

<u>Connections Among Science, Technology and Society</u>

- apply cause and effect reasoning to formulate relationships for a range of instances in which scientific evidence shapes or refutes a theory; and explain the limitations of science and technology in answering all questions and solving all problems, using appropriate and relevant examples

- describe and evaluate the design and function of technological solutions to practical problems, using scientific principles or theories; and relate the ways in which chemistry and technology advance one another, using appropriate and relevant examples

- explain and evaluate for a given instance, and from a variety of given perspectives, how science and technology are influenced and supported by society; and assess the ability and responsibility of society, through chemistry and technology, to protect the environment and use natural resources wisely

- identify subject-related careers and apply the knowledge and skills acquired in Chemistry 30 to everyday life and to related and new concepts in post-secondary studies of chemistry.

SPECIFIC LEARNER EXPECTATIONS

LEARNING CYCLE

The specific learner expectations consist of the knowledge, skills and attitudes that are to be addressed in Chemistry 20–30. The use of the learning cycle allows students to progress, from:

- an introduction framing the lesson in an STS connection relevant to the lives of the learners, and makes connections between past and present learning experiences, as well as anticipates activities to focus students' thinking on the learning outcomes of the activity

TO

- the experiential exploration of new content that provides students with a common base of experiences within which they identify and develop key concepts, processes and skills

THROUGH

- a hypothesis-building phase where concepts are developed to describe a particular aspect of their experiential exploration, and opportunities are provided to communicate their conceptual understanding, or demonstrate their skills or behaviours

TO

- an elaboration phase that extends understanding of key concepts and allows further opportunities to practise desired skills and problem-solving strategies

TO

- an application phase where the hypotheses, vocabulary and patterns previously developed are applied to new situations and related to key concepts and principles of science

TO

- a final evaluation of the significance of the new learning in an STS context to assess their understanding and abilities, and provide opportunities for evaluation of student progress toward achieving the curriculum standards.

In Chemistry 20–30, students examine phenomena in a variety of topics to show the relationships among all the sciences. Wherever possible, examples should be framed in the context of the learners' own experiences to enable them to make the connections between scientific knowledge and the society around them, the technology that societies have developed, and the nature of science itself.

PROGRAM OVERVIEW

The Chemistry 20–30 program emphasizes the science themes: *change, diversity, energy, equilibrium, matter* and *systems* as they relate to chemistry. These themes provide a means of showing the connections among the units of study in both courses of the program, and provide a framework for students to learn how individual sections of the program relate to the big ideas of science.

In addition to developing a solid understanding of fundamental science concepts and principles, Chemistry 20–30 has the goal of educating students about the nature of science and technology, and the interaction between chemistry and technology. Students must be aware of the tremendous impact of chemistry and associated technology on society, but at the same time, they must be aware of the roles and limitations of the chemistry sciences, science in general, and of technology in problem solving in a societal context.

CHEMISTRY 20

Chemical *change* and *matter* are the themes common to all the units in Chemistry 20. An understanding of the nature of *matter* and an analysis of its *changes* is essential for understanding what is happening and for predicting what will happen; control of *change* is essential for the design of technological *systems*. The principles of conservation of mass and *energy* help to predict and explain the *changes* that occur in a closed *system*. Chemistry 20 students are developmentally ready to begin defining *matter* in conceptual terms. Observations that provide evidence to support theories are stressed through experimentation and linking empirical and theoretical knowledge.

The major concepts allow connections to be drawn among the four units of the course and among all seven units in the two courses in the program.

Chemistry 20 consists of four units of study:

Unit 1: Matter as Solutions, Acids, Bases and Gases
Unit 2: Quantitative Relationships in Chemical Changes
Unit 3: Chemical Bonding in Matter
Unit 4: The Diversity of Matter: An Introduction to Organic Chemistry.

Each unit in Chemistry 20 uses a different context to investigate the nature of *matter*; to identify common patterns and the processes by which *matter* and *systems* are modified. Unit 1 focuses on the nature of *matter*, specifically solutions and gases, by examining their properties, identifying patterns and analyzing *changes* in these *systems*. In Unit 2, the quantitative relationships in chemical reaction *systems* are explored in predicting masses of substances reacted or produced as a result of chemical *change*. In Unit 3, models of the atom are extended to models of bonding as the properties of *matter* and theoretical explanations about its behaviour are linked. In Unit 4, examples of the *diverse* forms of organic compounds are investigated and compared with inorganic *matter*. *Change* as it relates to chemical reactions of organic compounds in living and nonliving systems is also examined.

CHEMISTRY 30

The themes of *change*, *energy* and *systems* are central in Chemistry 30. *Equilibrium* and *matter* are subordinate themes that are also addressed. The components of a *system*, which may be a collection of substances or processes, influence each other by the transfer of *energy* and *matter*. Changes to one part result in *changes* to other parts of the system. In a system at *equilibrium*, opposing reactions are balanced.

The major concepts allow connections to be drawn among the three units of the course and among all seven units in the two courses in the program.

Chemistry 30 consists of three units of study:

Unit 1: Thermochemical Changes
Unit 2: Electrochemical Changes
Unit 3: Equilibrium, Acids and Bases in Chemical Changes.

Chemistry 30 expands upon the concepts and skills introduced in Science 10 and Chemistry 20. Each unit in Chemistry 30 uses a different context to investigate the nature of chemical *change*. The themes are addressed using examples from inorganic and organic chemistry to emphasize the unity of science. *Energy*, as it relates to chemical *change*, is the focus of Unit 1. *Energy* as heat is most commonly absorbed or released in chemical reactions. Thermochemistry is the study of these heat *changes*. *Changes* in physical and nuclear *systems* are briefly explored for comparison. In Unit 2, *changes* in electrochemical *systems* are examined, oxidation–reduction reactions are analyzed, and the *energy* and *matter* involved are quantified. In Unit 3, the focus is on chemical *systems* at *equilibrium*. Few chemical reactions proceed in only one direction; most are somewhat reversible. Chemical *systems* involving acids and bases are studied as examples of chemical *changes* at *equilibrium*.

CHEMISTRY 20

UNIT 1
MATTER AS SOLUTIONS, ACIDS, BASES AND GASES

OVERVIEW

Science Themes: *Change, Matter* and *Systems*

In Unit 1, students gain an insight into the nature of *matter* through an investigation of *change* in the context of solutions, including acids, bases and gases. Viewing models of *matter* as *systems* undergoing *change* aids in their understanding of the underlying structure of *matter*.

This unit builds on Science 7, Unit 4: Temperature and Heat Measurement; Science 8, Unit 1: Solutions and Substances; Science 9, Unit 5: Chemical Properties and Changes; Science 10, Unit 1: Energy from the Sun, Unit 3: Energy and Matter in Chemical Change, and on Unit 4: Change and Energy. It provides students with a foundation for the study of stoichiometry and bonding in Chemistry 20 and electrochemistry, acids and bases in Chemistry 30.

The three **major concepts** developed in this unit are:

- solutions are homogeneous mixtures of pure substances
- acids and bases have an affect on aqueous *systems*
- a model of the gaseous state of *matter* provides insight into molecular behaviour.

In this unit, *students will develop* an ability to use the **skills and thinking processes** associated with the practice of science, emphasizing:

- initiating and planning
- collecting and recording data according to safety and environmental considerations
- organizing and communicating data
- evaluating the process or outcomes of the design of investigations into the properties of and *changes* to *matter*.

The STS connections in this unit illustrate:

- the central role of evidence in the accumulation of knowledge, and the way in which proposed theories may be supported, modified or refuted
- the functioning of products or processes based on scientific principles
- 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.

ATTITUDES

Students will be encouraged to:

- develop a questioning attitude and a desire to understand more about *matter*
- appreciate that scientific evidence is the foundation for generalizations and explanations about *matter*
- develop an awareness of the importance of water as a medium for chemical *change*
- value the need for safe handling, storing and disposing of chemicals and materials
- respect the usefulness of models and theories that are used to explain natural phenomena relating to the behaviour of gases
- develop an interest in the role of solutions, acids, bases and gases in daily life
- appreciate that our understanding of *matter* has been enhanced by the evidence obtained from the application of technology, particularly instruments for making measurements and managing data.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. Solutions are homogeneous mixtures of pure substances.	• the composition of solutions can be accurately described, by extending from Science 8, Unit 1, and Science 10, Unit 1 and Unit 3, the meaning of solute, solvent, dissolving, solution, solubility and the properties of water, and by: • providing examples, from living and nonliving systems, of how dissolving substances in water is often a prerequisite for chemical change • differentiating between electrolytes and nonelectrolytes • defining concentration in terms of molarity (moles per litre of solution) • using simple calculations to show different ways of expressing concentration; e.g., per cent by mass and volume, parts per million (ppm) • outlining the steps required to prepare a solution and a dilution of a solution • describing an equilibrium system in a saturated solution in terms of equal rates of dissolving and crystallization.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	***Students should be able to demonstrate the interrelationships among science, technology and society, by:***
	• **understanding solutions and their significance in living and nonliving systems; and ways of expressing and calculating concentration; and preparing solutions, using qualitative tests to identify solutions and ions in solution, within the context of:**
• using a simple conductivity apparatus to perform an experiment to identify solutions • using a balance and volumetric glassware to prepare solutions of specified concentration • performing an experiment to determine the identity of an ion, using simple qualitative tests, including solution colour, flame tests and solubility • writing dissociation/ionization equations for dissolved strong acids and ionic compounds • calculating, from empirical data, the concentration of solutions in moles per litre of solution and determining mass or volume from such concentrations • calculating, from empirical data, the concentration of diluted solutions, and the quantities of a solution and water to use when diluting • using empirical data and dissociation equations to calculate the concentration of ions in a solution.	• providing examples of how solutions and solution concentrations are applied in products and processes, in scientific studies and in daily life; and comparing the ways in which concentrations of solutions are expressed in the chemistry laboratory, in household products and in environmental studies **OR** • explaining the role of concentration in risk/benefit analysis and the significance of biological magnification in increasing the concentration of substances within ecosystems in terms of protecting the environment from harm to ensure quality of life for future generations **OR** • evaluating the risk involved in safe handling, storing and disposing of solutions in common use in the laboratory and in the home **OR** • investigating the application of the scientific principles of qualitative analysis in the practice of chemistry; e.g., careers in forensic science **OR** • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
2. Acids and bases have an effect on aqueous *systems*.	**• acids and bases affect the chemistry of aqueous systems, by extending from Science 9, Unit 5, and Science 10, Unit 3, the properties, formulas and names of acids and bases, and by:** **• defining acids and bases, ionization and neutralization, empirically and theoretically, based on Arrhenius' concepts** **• defining pH in terms of whole number powers of 10** **• describing the relationship between pH and hydrogen ion concentration; i.e., a change of 1 in the pH value is equivalent to a ten-fold change in the hydrogen ion concentration** **• calculating whole number pH values from hydrogen ion concentration, and hydrogen ion concentration from whole number pH values.**

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	*Students should be able to demonstrate the interrelationships among science, technology and society, by:*
	• **understanding that acids and bases affect the chemistry of aqueous systems by defining acids and bases, by differentiating among acidic, basic and neutral solutions, using simple tests, writing ionization equations, and calculating the concentrations of hydrogen and hydroxide ions in solution and pH, within the context of:**
• using indicators, pH and conductivity to perform experiments to differentiate among acidic, basic and neutral solutions • calculating concentrations of H^+ or OH^- for strong acids and bases • constructing a table comparing pH and hydrogen ion concentration in order to illustrate that as the hydrogen ion concentration increases, the pH decreases.	• providing examples of processes and products that use knowledge of acid and base chemistry; e.g., pulp and paper, car batteries, food preparation, cleaning aids OR • identifying some everyday processes and products that require knowledge of how to handle acids and bases; e.g., sulfuric acid in car batteries, never mixing bleach with household cleaners; treating accidental acid or base spills, using neutralization and dilution OR • assessing, qualitatively, the risks and benefits of transporting acidic and caustic substances in populated areas in terms of the need to protect the environment to ensure society's safety and quality of life for future generations OR • relating the concept of pH to its application in describing solutions encountered in everyday life and comparing the pH scale to others, like the Richter scale for measuring the intensity of earthquakes OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
3. A model of the gaseous state of *matter* provides insight into molecular behaviour.	• the behaviour of gases has been extensively described, and relationships quantified, by extending from Science 7, Unit 4, the concept of temperature and from Science 10, Unit 4, the kinetic molecular theory and how it accounts for the properties of solids, liquids and gases, and by:
	• performing calculations, using Boyle's and Charles' laws, and illustrating how they are related to the combined gas law
	• relating Boyle's, Charles' and Avogadro's laws to the ideal gas law
	• converting between the Celsius and Kelvin temperature scales and expressing atmospheric pressure in a variety of ways; e.g., mm of Hg, atm, kPa
	• performing calculations based on the ideal gas equation, $PV=nRT$, under a variety of conditions; e.g., standard temperature and pressure (STP), standard ambient temperature and pressure (SATP)
	• describing the behaviour of real and ideal gases, in terms of the kinetic molecular theory.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	***Students should be able to demonstrate the interrelationships among science, technology and society, by:***
	• understanding the behaviour of gases by relating the gas laws proposed by Boyle, Charles and Avogadro to the ideal gas law, describing the behaviour of real and ideal gases in terms of the kinetic molecular theory; and by drawing and interpreting graphs that relate pressure and temperature to gas volume; designing, performing and evaluating experiments to illustrate the gas laws, and carrying out calculations based on the gas laws, within the context of:
• drawing and interpreting graphs of experimental data that relate pressure and temperature to gas volume • designing and performing an experiment to illustrate the gas laws, which identify and control variables • performing and evaluating an experiment to determine molar mass from gaseous volume • using empirical data to do calculations based on the ideal gas law.	• providing examples of processes and products from daily life that illustrate the application of the properties of gases; e.g., breathing, olfaction, weather, scuba diving, ammonia fertilizer, internal combustion engine, steam turbine, hot air balloon, automobile air bag **OR** • describing, from a historical perspective, the central role of experimentation, and the development of technologies capable of precise measurement in the formulation of the gas laws **OR** • evaluating, in terms of the influence of the needs, interests and financial support of society on scientific and technological research, the advantages and disadvantages of using compressed gases as fuels; e.g., hydrogen, methane, propane **OR** • any other relevant context.

UNIT 3
EQUILIBRIUM, ACIDS AND BASES IN CHEMICAL CHANGES

OVERVIEW

Science Themes: *Change, Equilibrium* and *Systems*

In this unit, the concept that *change* eventually attains equilibrium is expanded to a quantitative treatment in reaction *systems* involving ideal gases and acid and base solutions. Students apply stoichiometric methods to titration experiments, further explore indicators and are introduced to buffer *systems*.

This unit builds on Science 8, Unit 1: Solutions and Substances; Science 9, Unit 5: Chemical Properties and Changes; Science 10, Unit 3: Energy and Matter in Chemical Change; Chemistry 20, Unit 1: Matter as Solutions, Acids, Bases and Gases, and Unit 2: Quantitative Relationships in Chemical Changes. This unit prepares students for post-secondary studies in related areas.

The three **major concepts** developed in this unit are:

- there is a balance of opposing reactions in chemical *equilibrium systems*
- acid and base *systems* are quantitatively and qualitatively described
- acid–base chemistry involves proton transfer.

In this unit, *students will develop* an ability to use the **skills** and **thinking processes** associated with the practice of science, emphasizing:

- initiating and planning
- collecting and recording
- organizing and communicating
- analyzing
- connecting, synthesizing and integrating
- evaluating the process or outcomes of investigations of *equilibrium*, acids and bases.

The **STS connections** in this unit illustrate:

- the central role of evidence in the accumulation of knowledge, and the ways proposed theories may be supported, modified or refuted
- the functioning of products or processes based on scientific principles
- the limitations of scientific knowledge and technology
- 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.

ATTITUDES

Students will be encouraged to:

- appreciate the usefulness of the mathematical model in describing chemical *equilibrium*
- value the role of precise observation and careful experimentation in learning about the chemistry of acids and bases
- tolerate the uncertainty involved in providing theoretical definitions for acids, bases and *equilibrium*
- value the need for safe handling, storing and disposing of chemicals and materials
- appreciate the complexity of environmental problems, such as acid deposition, that have no simple solution
- foster intellectual honesty, open-mindedness and objectivity when assessing environmental effects caused by chemical *change*.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
1. There is a balance of opposing reactions in chemical *equilibrium systems.*	• chemical reactions involving gases, acids and bases can be described as dynamic equilibrium systems, by extending from Chemistry 20, Unit 1, the model for equilibrium in a saturated solution, and by: • stating the criteria that apply to a system at equilibrium; e.g., closed system, constancy of properties, evidence of reversibility, equal rates of forward and reverse reactions • writing and interpreting chemical reaction equations for chemical systems at equilibrium • relating the reversibility of reactions in electrochemical cells to equilibrium • calculating equilibrium constants/concentrations for simple homogeneous chemical systems when: – concentrations at equilibrium are known – initial concentrations and one equilibrium concentration are known – the equilibrium constant and one equilibrium concentration are known • predicting if reactants or products are favoured in a reversible reaction, on the basis of the magnitude of the equilibrium constant • using Le Chatelier's principle to predict, qualitatively, shifts in equilibrium caused by changes in temperature, pressure, volume or concentration • explaining that catalysts do not affect the concentrations at equilibrium, only the time it takes for a system to reach equilibrium.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	***Students should be able to demonstrate the interrelationships among science, technology and society, by:***
	• understanding that many chemical reactions can be described as dynamic equilibrium systems by stating the criteria that identify them; writing equations, calculating equilibrium constants and concentrations for chemical systems at equilibrium, and by designing and performing experiments to analyze, qualitatively, shifts in equilibrium, within the context of:
• identifying variables and performing an experiment to test, qualitatively, predictions of equilibrium shifts.	• applying equilibrium principles to analyze everyday phenomena; e.g., the higher concentration of red blood cells in the circulatory systems of people living at high altitudes; carbon dioxide gas escaping from an open bottle of pop; the precipitation of limestone in caves; the rapid corrosion of metals in the presence of an acid; the role of oceans in the carbon cycle OR • analyzing industrial processes, such as the Haber–Bosch process for producing ammonia, and the Solvay process for making sodium carbonate, on the basis of equilibrium principles OR • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
2. Acid and base *systems* are quantitatively and qualitatively described.	• acid and base systems are quantitatively and qualitatively described in a variety of ways, by extending from Science 8, Unit 1, Science 9, Unit 5 and Science 10, Unit 3, the properties of solutions, acids and bases, and from Chemistry 20, Unit 1, the definitions for acids, bases and pH, and by: • explaining the pH/pOH scale in terms of logarithms • defining K_w, K_a and K_b • calculating $H_3O^+_{(aq)}$ and $OH^-_{(aq)}$ concentrations, pH and pOH for solutions, using the ionization constant for water, K_w • predicting, qualitatively, changes in pH and pOH when a solution is diluted • differentiating between strength and concentration in acids and bases on the basis of empirical properties • comparing strong and weak acids and strong and weak bases, using equilibrium principles • performing calculations to determine any of pH, pOH, $[H_3O^+_{(aq)}]$, $[OH^-_{(aq)}]$, K_a, or K_b from the masses of solute, volumes and concentrations of solutions • performing calculations to determine masses of solutes, volumes or concentrations of solutions from pH, pOH, $[H_3O^+_{(aq)}]$, $[OH^-_{(aq)}]$, K_a and K_b.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	***Students should be able to demonstrate the interrelationships among science, technology and society, by:***
	• understanding that acid and base systems are quantitatively described, using pH, pOH, $[H_3O^+_{(aq)}]$, $[OH^-_{(aq)}]$, K_w, K_a, K_b, and concentration; and by performing calculations to determine any of the above from empirical data, and differentiating among strong and weak acids and bases and other solutions, within the context of:
• designing and performing an experiment to differentiate among strong and weak acids and bases and a variety of neutral solutions • calculating K_a and K_b from provided empirical data.	• describing the significance of pH in the formulation of various products, in the maintenance of viable aquatic and terrestrial environments, and in the body fluids of living systems; and understanding the importance of chemical principles to explain the functioning of products and processes **OR** • tracing, from a historical perspective, the development of the pH scale as an example of the way scientists have always strived to improve communication **OR** • explaining the significance of strength and concentration in chemical spills, in transport of dangerous goods, and in acid deposition; and discussing the need for society and individuals to protect the environment for future generations **OR** • any other relevant context.

MAJOR CONCEPT	KNOWLEDGE
	Students should be able to demonstrate an understanding that:
3. Acid–base chemistry involves proton transfer.	• Brønsted–Lowry acid–base reactions involve proton transfer, by extending from Chemistry 20, Unit 1, the Arrhenius definitions for acids and bases and neutralization, and from Chemistry 20, Unit 2, quantitative relationships in chemical changes, and by: • writing and interpreting chemical reaction equations illustrating the Brønsted–Lowry definition of acids and bases and neutralization • identifying conjugate pairs of Brønsted–Lowry acids and bases in chemical reaction equations • defining and describing indicators and explaining their colour changes in terms of an equilibrium shift • describing examples of substances that can act as either proton acceptors or proton donors (amphiprotic/amphoteric species) • describing examples of substances that can accept or donate more than one proton, and writing and interpreting related chemical equations • performing calculations related to quantitative reactions between acids and bases, including excess reagents in strong acid–strong base combinations • differentiating between indicator end point and equivalence point • explaining how buffers maintain a relatively constant pH when small amounts of acid, base or solvent are added to an aqueous system • providing examples of buffers that operate in living systems; e.g., in blood.

SKILLS	STS CONNECTIONS
Students should be able to demonstrate the skills and thinking processes associated with the practice of science, by:	***Students should be able to demonstrate the interrelationships among science, technology and society, by:***
	• understanding the Brønsted–Lowry definition of acids and bases by analyzing, predicting and writing chemical equations for acid and base reactions; explaining indicators, buffers and titration; performing calculations related to reactions between strong acids and strong bases; and by designing, performing and evaluating experiments to investigate acids, bases and buffer action; performing a titration experiment, and drawing and interpreting titration curve graphs, within the context of:
• predicting the most likely acid–base reaction, using tables of relative acid–base strength • designing and performing an experiment to determine the properties of organic and inorganic acids • standardizing an acid or base solution, using primary standards • performing a titration experiment and related calculations to determine the concentration of an acid or base solution • using a pH meter and laboratory glassware related to titrations • using indicators to determine the approximate pH of an acid or base solution • drawing and interpreting titration curve graphs, using data from titration experiments involving acids and bases in various combinations, including: – a strong acid with a strong base – a strong acid with a weak base – a weak acid with a strong base – a strong acid with a polybasic species – a strong base with a polyprotic species • designing, performing and evaluating an experiment to test buffer action.	• explaining, from a historical perspective, the limitations of acid–base concepts in explaining observed phenomena and the ways in which proposed theories for acids and bases have been supported, modified or refuted OR • explaining, using chemical principles, the formation of acid deposition, describing the environmental impact and the measures being taken by industries to reduce emissions, and evaluating the problem of acid deposition, recognizing that a practical solution is limited by current scientific knowledge and technology and may require a compromise between competing priorities OR • analyzing, on the basis of chemical principles, the application of acids, bases, indicators and buffers; e.g., in processing and storage of food, in pharmaceuticals, in cleaning aids, fertilizers and other industrial products OR • any other relevant context.

Appendix E

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3H Periodicals in the Classroom
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3I An STS Context
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3J Controversial Issues
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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

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PRELIMINARY INFORMATION

Senior High Science Inservice Modules

A manual for workshop development and thirteen inservice workshop modules are included in this package. These modules can serve as a template for the planning and presentation of half day or full day professional development sessions. Such sessions and can be offered at the school, jurisdiction, convention or conference levels. These modules are designed to actively involve teacher participants as they follow through with the strategies outlined within each module. An interested teacher(s) or jurisdiction curriculum representative can easily facilitate such a workshop as appropriate background, specific activities, overheads and references are provided. Properly implemented these workshops will assist senior high science teachers to become familiar with teaching and evaluation strategies that support the new program directions.

It is desirable to encourage local teacher leadership using teachers with expertise and enthusiasm as facilitators of these modules. The facilitating teachers become directly involved, taking ownership of the inservice activity and tailoring it to meet local needs.

In some cases a jurisdiction, school, convention or conference committee will require an external "expert" educator. Many of the inservice modules in this package address topics covered in sections of the Senior High Science Teacher Resource Manual and in most cases they were authored by the same educator. In several cases, the author or another qualified individual is willing to offer these or complementary workshops for a mutually agreed upon sum. A list of educators prepared to offer such workshops is attached.

The modules included in this package are:

A Manual for Workshop Development
  A System-Based Development Model for Workshops

Module 1 – Teaching for Thinking
Module 2 – STS Teaching Strategies
Module 3 – Controversial Issues in the Science Classroom
Module 4 – Focus on Research
Module 5 – Science 10 – A Hands-On Sampler
Module 6 – Performance Assessment in Science 10
Module 7 – Technology and Media in the Science Classroom
Module 8 – Cooperative Learning
Module 9 – Teaching for Conceptual Change

Module 10 – Teaching with Gender Balance
Module 11 – Questioning Techniques
Module 12 – Environmental Connections in the New Science Programs
Module 13 – Agricultural Connections in the New Science Programs

Should you have any questions, concerns or comments regarding the content of these inservice modules, please contact Bev Romanyshyn, Inservice and Implementation Consultant, Curriculum Branch. Phone 427-2984 or fax 422-3745.

Senior High Science Video Series

The Senior High Science video series consists of 15 programs designed to facilitate implementation and to support the curriculum of new Senior High Science Programs. Programs 1 and 2 describe the intent and content of the new programs and the continuity between junior and senior high science. Programs 3 to 5 are for inservice, featuring teachers using strategies supportive of the intent of the new curriculum. Programs 6 to 8 convey science concepts for students. Program 9 demonstrates the diversity of careers available in science. Programs 10 to 15 present short, single concepts in chemistry, physics and biology for students.

Program 1 - *Baking Better Science*
This program provides an overview of new Senior High Science Programs for students, parents, administrators, counsellors, teachers.

Program 2 - *Zapped*
The impending new Senior High Science curriculum may find teachers feeling overwhelmed, or zapped. Interviews with classroom teachers, educators, business people, students document the need for change. The new curriculum is examined step-by step through its history, structure and impact on students and teachers.

Program 3 - *Teaching from the STS Approach: The Nature of Science*
Teaching from the Science/Technology/Society (STS) approach can help bring science to life for students. Commentary by Dr. Grant Mossop and interviews wth science teachers and educators explore the nature of science.

Program 4 - *Teaching from the STS Approach: Science and Technology*
Explores the relationship of science and technology. Commentary by Dr. Grant Mossop and interviews with science educators focus on developing student awareness of the use of science to solve problems in our lives.

Programs 5 - *Teaching from the STS Approach: The Social Context of Science and Technology.*
This program focuses on the social context of science and technology. Commentary by Dr. Grant Mossop and interviews with science educators highlight the benefits of this approach.

Program 6 - *Moving Mountains*
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.

Program 7 - *The Athabasca: A Case Study*
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.

Program 8 - *Back to the Sun*
This program examines the conversions of energy from one form to another, with a focus on renewable energy sources.

Program 9 - *Choosing Science*
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 reasearch team at the University of Alberta.
Program 10 - Superposition of Waves
Program 11 - Thin Film Interference
Program 12 - The Chemistry of Solutions
Program 13 - Reversible Reactions and Dynamic Equilibrium
Program 14 - Protein Synthesis
Program 15 - Movement of Matter Through Cell and Organelle Membranes

Appendix F

Letter of Invitation Sample

Dear "Science Team Member"

I am writing to request you participation in an interview involving members of the Alberta Education Curriculum Branch Science Team. This interview will be an important part of the data I will consider as I complete my thesis study. My thesis is a case study of the curriculum development process of the current Senior High Science Programs. I have included a draft copy of Chapter 5 of my thesis study to provide you with a context for this interview.

I will conduct this interview at a mutually agreed upon time and location. The interview will be audiotaped and videotaped to allow future analysis. Should you agree to participate please complete the attached consent form and bring it with you to the interview. The form requests that you to provide signed consent to record you part of this interview and to use selected quotes in my thesis study.

My purpose is to ask you to comment on aspects of the model of curriculum development that could be interpreted to have been implicit in the science curriculum project in which you played an important role. I will share some of the summary schematic portrayals of aspects of this model with you and ask you to comment on them.

I look forward to this interview and hope that you will be able to attend. Please contact me at 430-3600 if you have any questions regarding the interview.

Sincerely,

Desiree Hackman

Science Team Interview Participants Consent Form

I provide Desiree Hackman with consent to audiotape and videotape my part of the Alberta Education Science Team interview to be conducted on March 11, 1997. I understand that this record will be used for research purposes only, providing the data required for the development of an interview summary for her thesis study.

I also provide consent for the use of selected quotes from my comments during the interview within the draft thesis with the understanding that I will have the opportunity to read over the summary and approve, revise or reject any comments attributed to me.

A list of all Science Team members indicating their responsibilities within the Senior High Science Curriculum Development and Implementation Project is to be included in the appendix, as well as the interview summary and specific quotes used in the study. Anonymity, revision or removal of such references will be provided upon my request. This form will be a part of my files and will not be included in the thesis.

Name:______________________________

Date:_______________________________

Science Team Interview Questions

Senior High Science Program Manager

1. What do you consider to be the most important component of the curriculum development process?
2. Would you regard the proximity placement of the components as appropriate to represent the influence they had on the programs of study?
3. What was the purpose of the similar design framework among the programs? That is to say, what did it emphasize?
4. What was the importance attached to the careful articulation among and between the programs of study?
5. Why were the resource identification and professional development activities so extensive?
6. What were the advantages to staggering the implementation dates for the 10, 20 and 30 levels of the programs?
7. What do you feel is the significance of this curriculum development project to future science curriculum development projects within Canada and internationally?
8. What would you do differently if you had it to do all over again?

Inservice and Implementation Consultant questions

1. Why were the resource identification and professional development activities so extensive?
2. What influence do you think these activities have had on the implementation of the science programs?
3. What would you do differently if you had it to do all over again?

Science Team Interview Transcript

Interview with Senior High Science Program Manager

D: Question 1: What do you consider to be the most important component of the curriculum development process?

R: I'd like to make some preliminary remarks. I think first of all you should understand that my perspective highly idiosyncratic and it is very personal as well. Because the way I see the curriculum development process may not be the same way as perhaps others might see it, so there is going to be a lot of my own personal voice in this particular development process. I have always looked at the development process of curriculum has two major components: small p political and big p Process. You must be able to straddle both the political world and the process world. In the political world, you need to craft a sense of vision, then you have to show that you have support for the vision, and then you have to have a real commitment to making that particular change. In order to secure those kinds of support for a curriculum development process, you have to go out and talk to people.

H: In other words, the consultation and communication components are very important.

R: Yes, and you have to have a very clear idea as to what it is that you want to go about achieving and then how do you marshal resources and support in order to achieve those particular goals. It is not just something you do outside of Alberta Education. To be quite frank with you, you also have to do it within the Ministry as well.

R: The second aspect, the process aspect, I will use the term loosely as a technical process. You have to have a real good knowledge of what curriculum is, what curriculum development is, you have to have a really good sense of what curriculum trends are around the world. You have to have a library of resources you have to accumulate: whether it be documents from other parts of the world, other forms of curricula and then you have to, of course, create a team that can actually go about delivering this product or this artifact called a curriculum, curriculum study, curriculum guide or programs of study...

H: So what I hear you saying is that process has two components; contextualization in trends and emerging issues and so on.. and the other thing you mentioned was an assembly of personnel...

R: Yes they are, but fundamental to both is the ability to communicate what it is you are trying to do and then try to find a process by which we are going to achieve those results.

We briefly discussed the importance of a sense of direction and a sense of leadership...

R: When consulting about the vision - How is this going to achieve the vision? How is the suggestion going to achieve the vision? If they could not make a case, the consideration would be taken under advisement and nothing would be done about it.

H: It is difficult to portray a complex and dynamic process by means of one schematic. Therefore a series of supplementary figures is presented

R: This diagram (FIGURE 5.1) does a very good job of putting the pieces together because clearly in this province, and by the way we are very different than other provinces...we are committed, from a policy point of view of ensuring that our programs of study and the resources that we have, ... that there is a high degree of match between the two of them, so that having this team of people that was working on the senior high science programs, they were also the folks involved in identification and development of learning resources... a clear example is the Visions 1, 2, 3 texts for instance. Taking some, ..identifying some of the materials and then going to the publishers and saying "look, there are some pieces here that really don't fit, would you take them out or there are some pieces that are missing, would you consider putting them in." The belief that we have is that while you can have learning expectations statements here and yes they have the force of law, clearly we want to make sure that when you are making a big change and I think that perhaps the new programs of studies were perhaps a very major change, and I will talk about that more a little later on. We need to make sure that there was some support through resources...

We discussed how to represent the connection of the Visions 1,2.3 textbooks with the other resources on FIGURE 5.5. The Program Manager recommended another conceptualization. That is to conceptualize the resources as a continuum with three categories: in-house, resources developed in consultation with Alberta Education, and resources identified but developed externally.

D: Question 2: Would you regard the proximity placement of the components as appropriate to represent the influence they had on the programs of study?

R: program development considerations - developments in science education was more important than provincial policy directions...I wanted us to have the most forward-looking science education programs in the world and the policies were designed to support for me to have the opportunity to do that so for me this (science directions) were more important than this (policy directions). In terms of these two (changing needs of society - local level and in Canada) obviously we work within the province and changing needs of society at the local level was important as was the changing needs of society in Canada. In fact in the vision statement that we looked at this was quite important in terms of talking about how we are going to... just one aspect of the vision statement, how do we move from a resource based economy, which Alberta currently is, to at some point a knowledge based economy, by that I mean, not just saying that one day we will be totally without resources and we will have to work with them but there is some knowledge base stuff happening in resource-based economies as well.

H: Was there some shift in centrality as the project developed?...

R: I've got to be honest with you, this diagram does portray our considerations at the start and toward the end. In other words, goals of education didn't suddenly become more paramount than this. But I want to say a couple of things, just because these things are distant doesn't mean that they weren't used or that we hadn't picked them up via osmosis or some other means. So if you take a look at the documents, there is a clear relationship going back to them, but did we actually sit down and say, here are the goals of education and let's see how we can incorporate them. No, we saw them as supportive materials, but our, my centrality was here (science education).

D: <u>Question 3:</u> What is the purpose of the similar design framework among the programs?

R: Before I comment on that, this a question that is really very close to my heart and it is one that I am very passionate about. We have students taking, the same student taking biology, taking chemistry and taking physics or some combination there of. And yet we also have this other notion of what is the topology of a particular subject and then how that is, the word epistemology would be another way of looking at it and how that affects the curriculum, you know. And in the past we have developed a physics program and a chemistry program and a biology program in different time frames and they have all had different flavors. Here we were given a fabulous, fabulous opportunity to develop all of these programs at the same time. So we asked ourselves, what is the best possible design for science education, and when you think about the components of what goes into science education. We are always going to have skills expectations, we are going to have STS expectations, we are going to have some attitudinal expectations and then we are going to have some knowledge expectations. Right? Well given that there is so much overlap between three of the four, we figured, "Why don't we give it the same design frame?" Why don't we then try to level, as much as possible, the standard as expressed by the expectation statements, (we call them curriculum standards) and do that across the board for the different subject areas and then wherever appropriate you could then contextualize and weave in the knowledge portions as much as we could?

H: So you basically move the design framework from within a discipline and those considerations into a larger, more inclusive design framework. Sure.

R: Exactly!

H: And now the key question here is what did you see the need for and the advantages of doing this?

R: The advantage first of all is for the student. That's the way that I saw it. Clearly that if they are going to be experiencing certain skills in one subject area then they could hopefully transfer some of that to another area. To get teachers talking to one another, because suddenly they are confronted by things that are kind of similar because what we have now is a situation in some schools or in some areas where there is this silo-like approach and we wanted more dialogue and discussion. And there was another reason too. I didn't want to give them different designs in comparison to the Science 10-20-30 either. I wanted to make sure that ...

R: ...I could do through the curriculum, that I would try and level things off.

H: It is an articulation problem.

R: Yes, it is an articulation problem. The other thing was, we were also bound and determined through this revision process to try and wherever we could to soften the boundaries between the disciplines. Again because we were focused on student and to a lesser degree we were focused on the teacher needs, again I am being blunt, and the subject needs. Do you understand? If we had to make a choice and you said ... how would you prioritize how design considerations which were really high priority, student needs were more important. So if there was any way we could make a connection between the biology stream, the chemistry stream or with the physics stream, we would provide those points of contact for the student.

We discussed the evolution of the document. For example why the Vision is not shown as part of the Programs of Study on Internet. This could be an ease of access or format issue...

R: One thing that we did change, it was the course general learner expectations for knowledge, skills and STS expectations because we didn't have that at one time. And that was actually retrofitted...

R: If we were going to have students revisit a topic of study, we need to ask ourselves why. And if there are compelling reasons then we are going to deal with it in a different way if not then that's where we say oh my... I call it the redundant spiral so we wanted to make sure that that was also spaced out relatively well. It also provided us with audit check to make sure that we didn't have too much of one STS emphasis... one particular area as opposed to another to make sure there was a balance. It allowed us to do many, many, many things by using those particular charts. It had numerous purposes.

H: So this doesn't seem to be a problematic diagram...

D: Question 4: Why were the resource identification and professional development activities so extensive?

R: It was a huge change, we changed the structure and we changed what the program was going to be and ... here we had to try to provide a broader view. Do you realize that science is the only program of study that has an indication as to how you can possibly teach this stuff. It is called the learning cycle. Alberta Education policy is quite explicit. We only lay the standards out and we don't meddle in the nature of pedagogy. But because the nature of the change was so great and because of what we had put in, we managed to put in the learning cycle...

H: ... it is presented in a very general way, you can always argue and I'm sure you have that it is part of the background and the rationale and the context and the content of this change....

H: Would you say that it also had an implementation and political agenda to deal with the countless ways that teachers can resist any change, in the sense that if they didn't like this resource there was that resource, and there was that resource...and it was pretty hard to say no when you've got all this stuff.

R: The Minister of Education had made a clear statement that they were going to provide the necessary resources and support that teachers would need to make this change, among the many things he said. And that was grabbed upon and we did that. Now you are talking about providing those resources many, many times. Think of changes as being in a cloud. But no matter where you turn to look, whether it is resources, or it is professional development, whether it is curriculum documents, whether it is communication, it's all pointing in one direction. And ... very often when you want to make change, if you've got a system and subsystems within it and if they are pointing in the same direction, the subsystems, then if they are ready to bring about the change, your chances of change are marginally better than if you have subsystems that are pointing in every different direction.

R: Do you realize that the team here got to the stage where when someone would have a thought then the other person would be able to articulate the thought.

H: That's good teamwork.

R: We knew and trusted one another. It was, and is like a family. It was fabulous.

H: So that contributed to this common progression and adaptation....

R: Yes, there was never any tension or worry that the professional development activities were going to go off in another direction..

The discussion turned to FIGURES 5.7, 5.7a and 5.7b as they had not been discussed in adequate detail earlier.

R: Validate internal communication patterns That is how it works but I have to tell you that this team was pretty much given its own head to go ahead and do its job with very little interference...

H: Would you, in terms of fundamental validation that it is really the Science Team that is seen as the linchpin both within the internal communication and also within the external communication pattern?

R: Absolutely, the only people we reported to was that individual (the ADM) and keeping the Director informed obviously and this committee, the Ministers Advisory Committee....

H: So there was communication within all these levels at an appropriate level.

D: Related to this, I don't have a paper trail for this so if you could quickly validate this for me, these groups (Division Council and Management Council) meet on a regular basis, right?

R: Very regular. On a weekly or biweekly basis.

With respect to FIGURE 5.7b

R: R ranks the strength of the influence between the external group and the Science Team as follows:

1. Field validation teachers
2. Ministers Advisory committee
3. Subject area sub-committees
4. Alberta Science Teachers
4. Other science education stakeholders

5. Senior High Science Program Coordinating Committee.

R: Now I don't know what the interrelationship or the interplay was here. (arrow between field validation teachers and Alberta science teachers).

H: This was the inservice plan.

R: Yes and there was an interplay, an interrelationship but I don't have a good sense of, in relation to 1, 2, 3, 4, what the strength of this was.

H: I think this was basically from XXX thesis.

R: But there was a strategy here.

H: Yes, it was to go like that.

R: This by the way, we called our trap line (draws a connection between the Alberta Science Teachers and Other Science Education Stakeholders). That was the term that I used....

H: Why did you call them that?

R: If you had a problem, where you needed to fly something by. You know the small p political, you'd phone some people and say "We're thinking about doing this and this and this, what do you think? You know, without having to do it on an official basis.

H: You were testing the water.

R: You got it, yes. And I've carried this thing on to today. There are 2700 people on my trap line.

H: ... I think that the trap line is crucial, its absolutely crucial.

R: Its absolutely crucial and as I have said, having that vision helped, having a team committed to that vision helped, staying on course helped and of course sometimes when you had to make changes, we made them...

D: Question 7: What do you feel is the significance of this curriculum development project to future science curriculum development projects within Canada and internationally?

R: In general, I would say, using the Pan-Canadian Science, I would say just in small pieces, the notion of having a vision statement.

H: So its provided a template or a strategy for a larger group and a more diverse group to get together.

R: The work on attitudes from K to 12, those statements, the skills and STSE were developed on this floor in these offices here. Our sense of what the design of the framework should be has been influenced by the work and the experience of this curriculum development project. I think the notion of a common design principle has been taken and applied to the entire framework as a whole.

H: A language. Have you provided a language?

H I think we will terminate the interview here unless you have a closing thing you want to say.

R: Yeah, I just want to say one thing. I felt at the time that I was working on this project, and I feel it even more strongly today that we were very, very fortunate to do this at the right time because we had the resources to do it really, really well. And looking at the next round of changes, we are going to have to still meet the same quality criteria but the processes by which we are going to have to do it are going to be quite different and I am still sorting that out.

Interview with Inservice and Implementation Consultant

H: D has designed a series of schematics to attempt to portray the complexities of the curriculum development project.

Figure 5.1

D: Question 1:.What do you consider to be the most important component of the curriculum development process?

B: I think from my perspective it would be the communication and the consultation process which I feel that none of the other things would have been near as successful if there hadn't been such effective communication and consultation, not that it was perfect, there was lots of room for improvement.

H: What would you distinguish between the communication part and the consultation part, or would you?

B: I think there is some overlap there but I tend to think of the communication being beyond the consultation directly, where you are asking for opinions on programs of study or resources... something concrete that you are saying to folks, we want to hear. Whereas communication, say in professional devlopment was setting up mechanisms whereby the teachers that AE was working with felt very free and had many ways to get back and forth to us on any matter.

H: to be heard

B beyond the actual formal feedback forms of the meetings where teachers invited to respond by writing something down or somebody was recording

H: So as I hear you saying here, you touched on multiple avenues of communication both formal and informal, and I guess multiple opportunities for the exchange and the communication to take place

B: See I see the blurring happening when what I would think would be a communication and I would be picking up the phone to call a field test teacher about, say, a matter that I am returning a call because they are calling me and I find out thay have some particular thing in their classroom and they want advice is this the latest program or is this really the resource I am supposed to use and I find out that, during the conversation that there are other things that relate directly to development and then it becomes consultation. You deal with them on that individual problem but then you get them talking and you find out that they really hate page such and such of the Visions book and you know that there is an error on such and such a page and I would feed that back to the program managers and say hey, you know, so and so just told me and that may not have shown up on a formal feedback form so that is what I mean by a blurring where a communication mechanism not meant to formally elicit consultation ended up doing that. and I think that happened to you many times too...

D: Oh yes, more than once.

B: You would phone with a simple task and end up spending 35 minutes on the phone with somebody, just because you are open to that.

H: Further to that, D has developed a number of, ...because this is a very complex, sort of, general diagram, D has developed a number of other diagrams that get into the communication and consultation process a little bit more. So taking a quick look at this, in terms of identifying internal and external patterns. From your experience, how did you see the internal and external consultation and communication as interacting or influencing each other. Internal is within Alberta Education and its decisiobn-making structure.

B: I guess I saw a lot of interaction between the external and the internal that was ongoing throughout because there was so much consultation going on. The external feedback and the external informal communication that was going on every member of the science team was constantly feeding that back to the process and then that would be fed into internal consultation because it would result in changes to the program or the...

H: so the contents of the external communications...

B: were being funneled in all directions to the actual process of the revisions of the curriculum, and the development of the textbooks ... we met regulary and all of those things were shared and "Are you hearing anything like that?" So there was I think constant informal external communication that fed into the internal.

H: Were these the only things that the internal communication dealt with or were there other things within the internal consultations that were also taking place?

B: Yes, there were constantly internal concerns that the internal direction of the program, you know examining whether... were we indeed dealing with the major initiatives such as gender issues, were we really doing hands on science, was the inquiry there, those kinds of questions were constantly being asked, well, you remember, being brought to the table and if there was any move, we would be looking to see how it fit with the original vision and intent of the programs. That vision that came about sort of half way through the process that actually got written down, I think that there was constant attention to those kinds of matters. The internal communications swayed towards the time that implementation came about toward very much consideration of acceptance of post-secondary institutions, the trig, the mathematics..

H: So the substance of the consultations did change from the early stages to the later stages?

B: I think so. There were definitely things that were internal considerations that I don't think that external folks were attending to. It was more the program team wrestling with those and there were a lot of political things too that had to be considered that would be talked about internally but probably not in an external meeting...

D: I related, tried to relate the communication and consultation process to the development of the programs of study, specifically because of the, I think the consultation had the greatest influence on these directly. So I started out with what was the original framework, and my timeline shows that the consultation initially was internally until they had something that they were prepared to take to further committees. So the original framework would go through internal consultatation to get a draft program of studies, from there the consultation process, both internal and external, would expand and the science team was the conduit for feeding all of that information back into the programs of study so this is intended to be shown as a recursive process. That you would have a program of studies that would go through the internal levels of consultation, changes would be made, we would come back with revisions, we would go through external consultation and so on...

We spent a lot of time discussing improvements that could be made to FIGURE 5.7. Many of the suggested changes were incorporated into the schemata....

H: So that looks pretty good to your eye? (FIGURE 5.6 Professional Development)

B: Yes

We spent a lot of time discussing improvements that could be made to FIGURE 5.7a and FIGURE 5.7b. Many of the suggested changes were incorporated into the schemata.

We spent a lot of time discussing improvements that could be made to FIGURE 5.1. Many of the suggested changes were incorporated into the schemata.

B: ...the process is actually curriculum development that we are talking about and that this is kind of an organic thing that is going on.

H: So then how do you portray it?

B: and I was wondering about some kind of analogy like when you are writing about it. And I keep thinking about jello and thinking that that one would really work... but you know the more you think about jello, unless there is enough protein their, it won't gel right? And I see this as protein in the jello (consultation and communication). It's all through here. If you can imagine the jelly molds, these (the other three components) are all suspended in them in three dimensions and unless that communication and consultation gel the whole thing together...

D: Question 1 Why were the resource identification and professional development activities so extensive?

B: The resource activities were not out of line with what was going on in the other curriculum development projects since the Secondary Education Review. All of the programs that came on stream did all calls, and there was a real thrust to get into technology, to review software, to make sure that there were videos that were modern... But the difference in the senior high science program was that we couldn't find a textbook in the call and so the custom development added a level of complexity to that say of the social studies program or the math program that had been introduced in the past. But there was no book and nobody anticipated coming up with a book would be and how much involvement Alberta Education would need. The original idea was to find somebody to do it...so we really got pulled into that and there was way more resources...maybe it didn't show up in the books but the time of the Science Team that went into that than we ever would have been anticipating...Its hard to believe but the videos and all that, went on in other programs but it did...The Visions develop[ment was a unique component...so time we thought program consultants would have to spend on development they were doing on textbook development. It had a lot of pluses as well as minuses because everybody was waiting...Science got a lot of resources for things that they would never call professional development. Alberta Education provides inservice for field validation teachers and information sessions...If you were to compare the junior high science to the senior high science, I would guess that there was 20 times more resources for senior high science and that had to do with, I think, the political profile that the program had at the time.

D: Can you remember if there were background documents for the junior high science?

B: See these weren't only science background documents. They were cross-curricular background documents.

D: So to the best of your knowledge, although they weren't completed for the junior high science?

B: They were just draft, but the junior high science program manager would have read the precursor to these...

B: (pointing to the inservice modules on Figure 5.5) That was you and me. That was an idea, we heard a need and knew we had the expertise from the workshops teachers had given (at the Science 10 inservice).

H: You have identified texts and a lack of suitable resources in the thrusts of the programs as an impetus for th extensive resource development that Alberta Education had to embark upon. Was there anything in the consultation process that perhaps also gave you a bit of a direction or a sense of wat was need vis a vis resources?

B: Yes, I think that both the formal and informal communication that we were involved in. From these meetings we got a real sense of where the lacks were. That is particularly where the idea for the inservice modules came from. It was where our ideas for all of these background, exemplars or resources and teacher resource manuals came from... You would recall that we read through teleconference minutes and feedback forms what teachers were looking for and they were asking for direction and STS. They wanted video resources and we directly responded so there was a big influence of consultation.