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ABSTRACT

The 1990-91 school year is the year of elementary science in Saskatchewan. Precipitated by the Core Curriculum revolution, the implementation of new curriculum in all subject areas from K to 12 begins with science in 1990-91 and continues with other subjects for almost ten years. Scheduled to be implemented after careful assessment and pilot projects are Arts Education in 1991-92, Language Arts and Mathematics in 1992-93, and other subjects in the following years. Science has been subject to the most thorough and extensive review, evaluation and re-design that any curriculum has undergone in the history of Saskatchewan education. As a result a new emphasis on developing scientific literacy and focusing on the uses of science has emerged. The articles in this monograph were written to describe, explain and support the new curriculum to practicing and prospective teachers and others. They were first published in the "Northerner," the weekly newspaper in La Ronge, Saskatchewan. They were written from a northern Saskatchewan base, but are totally applicable to all of Saskatchewan and beyond. Parts 1 to 4 outline the philosophy and characteristics of, and reasons for, the new program. Part 5 outlines scientific literacy; part 6 introduces the new emphasis on science, technology, society and environment; and part 10 gives examples of how the Common Essential Learnings, the heart of Core Curriculum, may be implemented in science. Articles 7 to 9 go into some detail in exploring the nature and epistemology of science in response to the exhortation of the Science Council of Canada to teach an authentic view of science in Canadian schools. Finally, part 12 traces the picture of the awakening science program in northern Saskatchewan. (Author)

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School-Based Programs

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SCIENCE IN THE SCHOOLS

Howard H. Birnie

April 1991

Monograph No. 3

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Dr. Howard H. Birnie, formerly Professor of Education and Associate Member of Physics at the University of Saskatchewan in Saskatoon is a Science Consultant for the Northern Lights School Division in Northern Saskatchewan.

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Science and technology are very influential in today's societies, but they must not be allowed to control them. Science has become recognized as one of the basic subjects in today's schools. No one is liberally educated who is not scientifically literate. It is my hope that this monograph may contribute in some small way to achieve scientific literacy.

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PART 1: THE YEAR OF SCIENCE

The subject of science is receiving more emphasis than usual in the elementary schools of northern Saskatchewan in the fall of 1990. The reason is that this is the year of implementation across the province of a new science curriculum and program for Kindergarten to Grade 6 (K-6) .

Science is the first of the areas which are studied in the elementary school to be subject to complete revision under the province's new Core Curriculum policy, a policy for improving schooling which has already gained Saskatchewan international recognition.

In this series of articles, I would like to consider many aspects of the revolution in science teaching.

Over the past few years school programs in Science have undergone provincial assessment, pilot project writing and testing, and finally, in the fall of 1990, implementation. Saskatchewan Education (formerly the Department of Education) has a ten year implementation plan for the revolution in education precipitated by the Directions and Core Curriculum recommendations and this is merely the unfolding of the first major step, right on schedule. Incidently, the last revision of the elementary science curriculum guide took place in 1971, so it was long overdue regardless.

The Northern Lights School Division has developed its own implementation plan known as the Caribou Plan which parallels the provincial schedule in most respects . Other provincial and band controlled schools which utilize Saskatchewan curriculums are roughly following the provincial schedule. Arts Education is the next subject area to be implemented in 1991- 92, and Mathematics and Language Arts will follow in 1992- 93. Teachers are field testing new materials in these subject areas .

Core Curriculum is the product of a major review of education which began in Saskatchewan in 1981, which involved local meetings, surveys and receiving briefs, and resulted in the Directions report in 1984. One of the central recommendations of the Directions report was that education in Saskatchewan should be focused around a Core Curriculum.

Core Curriculum has two major and several minor elements. The first major element is that the basis of the school program will be the required areas of study (RAS) consisting of language arts, mathematics, science, social studies, health education, arts education, and physical education. Each required area has knowledge and values which make it a unique subject for study. The second major element is the common essential learnings or CELs as they have become known. The CELs consist of communication, numeracy, critical and creative thinking, technological literacy, independent learning, and personal and social values and skills. The CELs have been rigorously investigated and defined and the new science curriculum guide contains extensive suggestions for incorporating them into each required area of study.

Other recommendations in Core Curriculum included changes in time and credit allocations, the adaptive dimension and the use of locally developed options. The adaptive dimension relates to modifying courses to meet student needs and individualizing instruction. Another recommendation, called locally- determined options, is intended to cater to local and community program priorities. At the elementary level, a maximum of 20 % of time in the subject may be given to locally developed options and materials, so important to community education.

While school divisions were expected to provide some support for the implementation of the new Core Curriculum, Saskatchewan Education provides financial and other support through the Educational Development Fund (EDF), a program of long- term assistance to education which includes and goes beyond Core recommendations.

The major emphasis of the new science program, which includes elementary(K-5) at this time, and middle years(6-9), and secondary(10-12) later, is a shift from a focus mainly on science content, to a focus on both content and using science processes, attitudes, epistemology, and values in everyday life. The aim is to assist students in becoming scientifically literate, a term which encompasses all the attributes mentioned above and which will be the subject of a future article. An important part of scientific literacy is encouraging students to understand the relationships among science, technology, society and environment, commonly referred to as STSE. In addition, attention will be paid to both the strengths and weaknesses of science and technology, in the hope that in the future people will continue to control science and not the reverse, which is of some concern today.

The first of a two- day orientation workshop to the new elementary science curriculum guide has been conducted in a dozen schools in northern Saskatchewan by Daryl Arnott, Curriculum Coordinator for the Northern Region of Saskatchewan Education, and Howard Birnie, Science Coordinator for the Northern Lights Division, assisted by teachers who had run pilot projects in science in the last two years. These teachers were Rita Boyko of Pre- Cam in La Ronge, Valerie Bear of Valley View in Beauval, and Bill McMaster in Ile a La Crosse. All but a few elementary teachers had attended one of the initial workshops by the end of October. The second implementation workshop will be held in January and February of 1991.

PART 2: PHILOSOPHY AND CHARACTERISTICS OF THE NEW ELEMENTARY SCIENCE PROGRAM

There were many factors which influenced the direction that science teaching should take when the new curriculum guide which is being used in science in elementary schools across Saskatchewan this fall was being constructed.

Although the expression "curriculum guide" is always employed. it is at least partly misleading. Elementary science teachers have a professional obligation in each grade to expose their students to certain compulsory science topics called Core Units in the new curriculum. In grade two, for example, the Core Units are Habitats, Magnets, Plant Growth and Weather. The grade three teacher has the right to expect that these topics must have been covered in grade two, except under special circumstances.

In addition, grade two teachers may round out their programs in science by choosing from several Optional Units. Selected so that the science program in each year of schooling represents a broad coverage from all the branches of science, for example biological sciences and physical sciences, the Optional Units written at the grade two level are Air and Water, Dinosaurs, Foods, Measuring Matter, and Oceans.

The word guide implies that although there are certain topics to be covered in each grade which are compulsory and some which are optional, the manner in which the science program is designed. its scope and sequence and the methods by which it is taught, as examples, is the responsibility of professional teachers. This is where their expertise lies. The curriculum guide is full of lists of resources and ideas from which teachers may draw as they "build" an exciting science program for the year, integrating it skillfully with other Required Areas of Study(RAS).

The characteristics of the curriculum are derived from the philosophy of the curriculum team which is established legally in Saskatchewan Education. This philosophy is the set of beliefs which underlie the science program. What is the nature of learners? What is the nature of learning ? Do we believe in the basic right of every student to receive twelve years of formal schooling? Do we believe that the teen age student (middle years) has different characterictics and therefore demands different teaching approaches ? What is the nature of science and how is it different from other subject areas or disciplines as they are sometimes called ? Is a laboratory experience necessary for learning science?

In Saskatchewan, Dr. Paul Hart of the University of Regina was selected to investigate what is presently believed about the teaching of science in the province and around the world. His report led to a survey of the beliefs of teachers in Saskatchewan, and a study of science in practice and the research literature. Utilizing his report and recommendations, meetings called deliberative conferences of science teachers were held in every region in Saskatchewan. Based on these results, the Science Curriculum Advisory Committee gave its charge to its curriculum writers to design a curriculum with the following characteristics.

Since one of the philosophical beliefs of the curriculum committee, supported by the best research available, is that learning is superior if the learner is actively involved rather than sitting passively, the new science curriculum is activity- oriented. A hands- on, concrete materials approach is used to learn science. This approach leads to an inquiry- based program, in which students, under strong guidance and facilitation by the teacher, are given opportunity to find out some things for themselves. Skillful questioning by student and teacher develops thinking skills such as inferring and hypothesizing. This type of program relies on concrete materials such as construction paper, seeds and modeling clay, most of which are readily available and inexpensive, often found around homes and schools, but some of which, like balances and magnets, must be purchased from commercial suppliers. A good science program requires materials which are easy and convenient for the teacher to obtain.

Another characteristic of the new curriculum is that through the recommendation of the use of a wide variety of instructional approaches, an appeal to different learning styles, and an emphasis on outdoor and community education, it tries to create a stimulating learning environment.

One of the key elements of the Core Curriculum philosophy is a belief that learning is best when science is integrated with other Required Areas of Study, like Mathematics and Social Studies. Some teachers prefer to organize the RASs around a single theme, which facilitates integration. The study of the theme of Winter as one example could easily address Science, Language Arts, Art, Music, and Native Languages.

Finally, the new curriculum is designed to be user- friendly for teachers, constructed to address their teaching requirements. The guide is designed for teachers who do not have an extensive background in science. The guide contains a variety of suggestions for method, objectives to be covered, assessment techniques, and lists of the excellent resources available for teaching science. Further, ideas for assisting students to become scientifically literate, a major thrust of the program and the subject of a future article, and for incorporating the Common Essential Learnings, a key part of the Core Curriculum revolution, are abundant.

Of course, all these functional characteristics of the new curriculum guide are impotent without a dedicated science teacher. The teacher continues to be the heart of successful science teaching and schooling.

PART 3: CURRICULUM INITIATIVES IN THE NEW ELEMENTARY SCIENCE PROGRAM

When a new curriculum guide is being written for a given subject area in Saskatchewan schools, many decisions have to be made about its nature and format. Preparation of curriculum guides in Saskatchewan has almost always been directed centrally by the provincial government, where the responsiblity for education and the school system lies constitutionally. In the case of the new science curriculum guide, teacher writer- developers have been seconded and hired through advertising by Saskatchewan Education to create the document, which goes through many revisions, under the directions of a large committee called the Science Curriculum Advisory Committee, made up of teachers, administrators, professors, and officials from Saskatchewan Education.

The Science Curriculum Advisory Committee based its decisions mainly on the Paul Hart report, a survey of the literature of practice and theory in science, which led to several recommendations, and of the opinions of Saskatchewan science teachers. In this article, I would like to look at a number of curriculum initiatives which derived from this work and which the curriculum writers attempted to incorporate into the guide for science teaching in the elementary schools. Much of this article is based on the facilitator's notes taken from the implementation workshops prepared and organized by Saskatchewan Education, for which I express appreciation.

Content from the many sciences such as physics, chemistry, astronomy, geology, agriculture and biology, continues to be emphasized in the new elementary science program. However, there is a shift in emphasis toward the use of science and technology in society, with special attention being paid to environmental concerns. All the publics to be served by the schools, such as post-secondary education and students who do not go on to post-secondary education, were considered in selecting content.

A second initiative to be addressed in the new guide is the Common Essential Learnings(CELs), which is the main reason for the revision in Saskatchewan curriculum materials. The CELs such as Numeracy, Creative and Critical Thinking and Technological Literacy, which are emphasized in each science activity, are clearly identified.

An attempt has been made to offer suggestions on how all students may gain a greater awareness of the Indian and Metis people of Saskatchewan and their perspectives toward the environment. The use of a resource book on Indian stories called Keepers of the Earth suggests discussion topics and activities which provide a more meaningful and culturally identifiable experience for Native children in science, and promote the development in all students of positive attitudes toward Native peoples.

The curriculum attempts to promote equity in science by expecting active participation of both males and females. Every effort has been made to eliminate stereotypes of scientists as males only, and of scientists as white- coated recluses. Many reports have concluded that young women are opting out of science and technology courses and vocations, necessitating special attention being paid to attracting them to science and technology. When about 50 % of the population is female and our society is short of scientists, it makes no sense not to draw an equal number of scientists from this intellectual pool.

The Adaptive Dimension, which is part of the Core Curriculum recommendations, is designed to accommodate a wide variety of needs in the curriculum. Teachers are able to modify or extend the science activities listed in the curriculum guide. In some cases remediation or enrichment may be required or adjustments made for differences in reading levels; in others, locally- development teaching units may be more appropriate than those included in the texts.

Another initiative in the new science curriculum is its reliance on what has become known as resource- based learning. Resource-based instruction is a student- centered approach to curriculum usually involving planning by both teacher and teacher- librarian utilizing a broad variety of resources such as tapes, computers, field trips, and books, to name a few, in promoting lifelong learning skills. The new science curriculum recommends a broad range of exciting resources.

Finally, the science curriculum writers have tried to convince all teachers to do what successful teachers have always done, broaden both their instructional approaches, and assessment and evaluation techniques.

The list of teaching approaches available to today's teachers is impressive: activity packages, brainstorming, debate, demonstrations, discovery, discussion, drill and practice, field trips, small and large group work, independent study, interviewing, laboratory activity, learning centres, lectures, peer tutoring, role playing, science shallenge, simulation, and surveys.

It also follows that if the major goal of the new science program is to produce scientifically literate persons, then evaluation strategies should be broadened to test the extent to which this has been achieved. Since scientific literacy involves the nature of science; scientific thinking processes, values, interests, attitudes and technical skills; knowledge of science; and an understanding of the Science- Technology- Society- Environment(STSE) relationship. the standard evaluation technique, paper and pencil tests, is inadequate. Other techniques which may be employed to examine the expanded objectives which teachers are trying to accomplish include anecdotal records; contracts; observation checklists; projects; rating scales; student portfolios and journals; essay, objective and oral tests; test stations; and written reports.

The new curriculum guide is impressive, a state of the art document and has been well received by teachers. It needs to be; it must serve as a model for guides to follow in the near future.

PART 4: WHAT SCIENCE IS NEEDED IN THE SCHOOLS ?

In the relatively short history of teaching science in Saskatchewan schools, the major purpose has always been to pass on to students what is called the content of the subject- facts, concepts, principles, hypotheses, theories and laws: in short, the knowledge of the various branches of the subject of science- physics, chemistry, biology, geology, and astronomy. The question which educators must always consider is one which asks if this is the kind of schooling and education in science that will best serve all students who come to our schools, those who will go on do advanced studies by majoring in science or engineering, those who need a solid science foundation in the study of other related careers such as nursing or other health occupations or through an apprenticeship program, and those students who do not go on to any form of higher education, certainly the majority of our citizens ? In addition, should one take seriously what type of unique science program will best serve northerners ?

Of course, if you study written documents such as curriculum guides which formally outline the program to be followed in science in the schools, colleges and universities, you will discover lip- service being given to other objectives, such as learning how to employ the scientific method, identifying scientific attitudes, studying the uses of science in society, and what is meant by scientific thinking, but these have always been of secondary importance and never taken very seriously. If you examine the documents you will find that in addition to being stated in the objectives section, these objectives have rarely been treated further. Apparently it has been assumed that such objectives will be mastered automatically or concomitantly, as if by osmosis.

The acid test of the status of these secondary topics in science courses is to look at the examinations and assignments given to students at the end of the year or at the end of a teaching unit. These exams are almost always exams assessing mastery of content or knowledge exams, overwhelmingly factual repetition and regurgitation, with a few token questions dealing with comprehension and application, usually examined through problem solving. Rarely will you find questions which deal with the utility of science for everyday life.

It should not be surprising then to learn that in its study of science teaching in the elementary and secondary schools of Canada chronicled in Report 36 in 1984, the Science Council of Canada expressed concern that Canadian students had little idea of how science and technology operated in society and carried away from the schools many misconceptions about the true nature of science. To alleviate this concern, it recommended that a key objective of science courses in the future be for students to learn about the authentic nature of science and about the science- technology- society- environment (STSE) connection.

Science(and mathematics) have the reputation of being among the most difficult subjects in schools, especially secondary and post-secondary schools. Students often report that what is studied in these subjects does not seem to be relevant to real life. The irony is that all citizens become involved in myriads of science- related social decisions during school and after they become citizens, from how to use microwave ovens and electricity safely, to whether to allow the United States to test cruise missiles in northern Canada, to whether it is worthwhile to assist in cleaning up the Montreal River, to what environmental conditions are to be met to allow Sask Power to build dams and power plants on rivers in the north and in other areas of Saskatchewan.

Nothing that has been said above should be taken to indicate that science as defined mainly as content in recent curriculum guides has necessarily been poorly taught in the schools. There is some evidence to suggest that science in Canadian schools is as well presented as it is in most other countries. The Science Council was more concerned with what topics were included in the science curriculum and what currency the treatment of these topics had for students of all abilities and needs who inhabit our schools, not just for the intellectually elite.

Science courses in secondary schools such as physics, chemistry, geology and biology have been designed to serve primarily as entrance courses to their respective departments at the universities and other institutions of post- secondary learning and the topics such secondary school courses cover have been directly or indirectly dictated by these departments. In addition, teachers who major in biology or some other natural science develop a strong loyalty to these university departments and this loyalty colors the teaching that they do in the high schools. These adherents interpret their loyalty to be to the science departments or disciplines first and the school and students of all abilities second. As the expression goes, they teach science rather than students.

In this article, I have tried to make two points. The first is that in this scientific and technological age, science in the schools must go beyond knowledge to deliberately involve students in discussions and activities which emphasize how to use scientific knowledge. Certainly, there can be no doubt that scientific knowledge is essential- did you ever try to think in a knowledge vacuum ? But the utility of that knowledge and an understanding of the nature of the subject(science) that spawned it is of equal importance. Secondly, science programs in the schools must address the needs of all the publics served by the schools- business, the service industry, trades and other occupations, cultural and minority groups, post- secondary institutions, and the general public. This requires a science program which has a solid knowledge base, but goes much beyond that.

PART 5: WHAT IS SCIENTIFIC LITERACY ?

With the revolution taking place in science teaching in Saskatchewan has come a new expression- scientific literacy. Each discipline has its own jargon or technical language and science education is no exception. The expression is really not that new, however, having first been coined some twenty years ago.

The major aim of the new K- 12 Science program in Saskatchewan is to develop scientific literacy in students. That program is in various stages of development and implementation: the Elementary part(K-6) is being implemented this fall; the Middle years section(7- 9) is just beginning to be created and will go through writing, field-testing and revisions before being implemented in 1993- 94; and the Secondary courses(Grade 10; and Physics, Biology and Chemistry 20 and 30) are being field tested this fall for the first time, some of the pilots being directed by teachers in the schools of Northern Lights School Division.

For Saskatchewan schools, scientific literacy has been defined by seven Dimensions of Scientific Literacy, which are the foundation for the revitalized curriculum. Actively participating in K- 12 Science will enable a student to:

1. Understand the nature of science and scientific knowledge. Science is a unique way of knowing.
2. Understand and accurately apply appropriate science concepts, principles, laws and theories in interacting with society and the environment.
3. Use the processes of science in solving problems, making decisions, and furthering understanding.
4. Understand and appreciate the joint enterprises of science and technology and the interrelationships of these to each other in the context of society and the environment.
5. Develop numerous manipulative skills associated with science and technology. Many of these deal with measurement.
6. Interact with various aspects of society and the environment in ways that are consistent with the values that underlie science.
7. Develop a unique view of technology, society and the environment as a result of science education, and continue to extend this interest and attitude throughout life.

Each of the seven Dimensions has been further defined by a series of factors. Science teachers are expected to make these Dimensions and Factors an integral part of their science courses, which represents a major deviation from the almost total emphasis on content or subject matter which characterized and dominated past science teaching.

In the remaining part of the article, I would like to describe each Dimension in more detail, but before doing that, a word of caution. The aim of scientific literacy should be regarded as ideal; in all my years in science I have met few scientifically literate people. The mission of science teachers should be to assist students in making progress toward scientific literacy; that is a much more realistic and achievable goal for each science teacher in each grade.

The descriptions which follow are based on the Curriculum Guide published by the Government of Saskatchewan.

Dimension 1, nature of science, has been defined as having nine factors. Two samples factors are public and replicable. Scientists make their results public by publishing them. Only those public findings which can be replicated by others retain scientific validity. The curriculum identifies thirty- three key concepts as representative of present knowledge in science up to the end of secondary schooling. Concepts such as change, quantification, system, cycle, and entropy are included in Dimension 2. Dimension 3 refers to Processes of science, generally interpreted to be creative and critical thinking skills. Among the twenty- one to be studied and actively employed in science programs are classifying, hypothesizing, inferring, controlling variables and interpreting data.

The interaction between Science and Technology dominates Dimensions 4 and 5. In the former, such things as the interdependency of science, technology and society, and strengths and limitations of science and technology, are paramount. In the latter, the student is expected to develop a number of science-related skills such as using magnifying instruments and computers; measuring volume, temperature and mass; and manipulating laboratory equipment.

Probably no Dimension has more currency today than the sixth which deals with the values that underlie science. These basic beliefs, or what scientists put their "faith" in, include curiosity, questioning, respect for logic, demand for verification, and consideration of the consequences of their actions and discoveries.

The final Dimension concerns science- related interests and attitudes. Teachers are expected to assist students in seeing how science may play a part in the lifelong learning process through such things as interest in science in the media, as an avocation, and as an explanation for their observations and research, among others.

It should be obvious that to achieve the new aim of scientific literacy in the revitalized science program requires creative and imaginative teachers as facilitators of learning, and probably implies considerable change from the way science teachers have taught in the past. Saskatchewan has always had a strong teaching force (a number constantly being lured away by other western provinces) and I am persuaded that they will rise to the challenge.

PART 6: SCIENCE AND TECHNOLOGY IN THE SCHOOLS

One of the important differences between the world in which we live today and the world of one hundred years ago (or even one generation ago), is the presence in our world of many devices, hardware, and machines which are the products of an age of technology. Television sets and satellites, computers, automobiles, table forks, mirowave ovens, and hair dryers are only a few disparate examples of the innovations of technology.

A careful look below the surface will reveal that technology shapes, and is shaped by, society. Each new technological artifact carries with it inherent risks and benefits. Television may have made global communications and understanding more possible, but what effect has it had on childrens' ability to read ? The internal combustion engine may move us farther and faster, but what are the exhaust gases doing to our planet ? Clearly, the uses of technology demand carefully weighing the advantages and disadvantages.

It is not difficult to convince oneself that down through the pages of recorded history technology has been and continues to be one of the major contributors to changes in our society. The knowledge explosion of the last few centuries has undoubtedly been produced by the interdependence of science and technology. Until modern times technology has always been considered the dependent of science; indeed, technology has often been defined as applied science.

While the idea that technology (and to a certain extent engineering) may be thought of as applied science was satisfactory in the past, this assumption is woefully inadequate today, probably because of the fantastic advances in technology. In addition, the earlier belief implied that science always preceded technology. In fact, today, more often technology leads science, and develops long before science provides theoretical understanding of why a process or device works, which then allows improvement and remodelling of the technological advance. Perhaps more importantly, the development of technology often provides the scientific problems that lead to the advancement of science. Nevertheless, the two remain intimately related. The electrical theory of the light bulb was well- understood before Edison used a trial and error approach to develop a useful, durable, inexpensive filament. James Watt's steam engine, on the other hand, preceded in time the scientific theories which were eventually conceived to understand its operation. Considered separately, neither science nor technology is as productive as when they are applied together.

In recognition of the staggering importance of technology as our society approaches the twenty first century, curriculum makers across Canada have sought to make a place for it in the essential learnings of every student. The Science Council report of science across Canada(1984) proposed the initiation of a separate Technology course, and also the study of the science- technology- society connection as part of the Science course. The Hart Report of science in Saskatchewan(1987) extended the connection to science- technology- society- environment(STSE) and made it the focus of the revitalized science program now being introduced in the province. The Core Curriculum committee in Saskatchewan (1987), the recommendations of which have revolutionized education in the province, chose Technological Literacy as one of six Common Essential Learnings (CELs) which all students should study in every year of their schooling.

In addition, both the federal and provincial governments continue to insist that our future as a nation lies in our technological and hi- tech capability and our capacity to compete internationally.

As a first- order approximation, we may use a dictionary definition of technology. A typical dictionary may give several interpretations of technology: (i) application of scientific knowledge to practical purposes; (ii) body of methods, processes, and devices resulting from such application; and (iii) any use of materials or objects as tools to serve human needs.

While admitting that the relationship between science and technology is increasingly complex and that the boundaries of the two undoubtedly overlap, a more advanced separation may help us to resolve the educational issues surrounding them. Technology studies human- made products and processes, is more empirical, emphasizes methods and materials, and is valued for how well it works. Science, on the other hand, studies natural products and processes, is more theoretical in nature, emphasizes ideas, and is valued for how well it explains and predicts.

However, technology has developed its own techniques, processes and concepts. It uses observation and experimentation. If we employ the definition of a science as any branch of systematized knowledge, especially one in which techniques and principles of the scientific method are followed, paradoxically, technology may be a science.

As short a time as 5- 10 years ago, 4 % of all Canadian homes had a microwave oven; today the figure has risen to about 75 % Do we all really need this technological cookie ? Can our strained energy supply support this addition to our already voracious appetite and its environmental implications ? Is this an example of humans allowing themselves to be controlled by technology, instead of the reverse ?

These are the types of questions and answers which will effect the society of the future. Should our schools be assisting children in developing and honing the skills to deal with them now and in the future ? Should Technology be allowed a more extensive role in the schools curriculum as a subject of its own or part of the science course ? The experts think so; how will our schools, teachers and the general public respond ?

PART 7: THE EPISTEMOLOGY OF SCIENCE

If our schools do nothing else, they should acquaint students with the methods, processes and sources by which we build up the knowledge we possess, what is known as epistemology. They rarely do this. How has the knowledge that we attempt to pass on to our students in our schools developed? How do humans know what we know? What basic assumptions do we make as we collect and store knowledge ? It turns out that humans have several " ways of knowing", and each method of discovering knowledge differs in some fundamental respects from the others. Examples of branches of knowledge that conceptualize their "truths" by different processes are religion, history, the oral tradition, use of language, and science.

Epistemology is the branch of philosophy which analyzes the origin, nature, methods, and validity of human knowledge. In this article, as we continue in our quest to better understand science and its place in the schools, we will consider the basic assumptions of science and how science compares to other "ways of knowing". This will be a first- level, simple investigation. In fact, philosophers may not even regard it as rigorous enough to be called philosophical discourse and, quite frankly, I'm not knowledgeable enough about advanced philosophy to do much about it.

Let's get our teeth right into it. Which are we to believe- creationism or evolution ? This basic conflict between religion and science continues to encourage scholars to protracted and unresolved discussion and argument. I would like to suggest that the problem lies in the lack of recognition of the basic assumptions, set of beliefs, and authority from which each side is arguing.

Religious and theological fundamentalists believe that their source of knowledge is a divinely- inspired book or its equivalent, such as an infallible interpreter, as its authority. To some, the knowledge from this book is dogmatic and absolute, the ultimate truth. More liberal theological scholars may have slightly different interpretations.

Scientists, on the other hand, employ observation and experimentation using the senses, and extenders of the senses such as microscopes, to build up knowledge which is never absolute but regarded by most scientists as "working hypotheses" and theories. (Of course, there are some scientists who regard it as absolute.) Thus, scientific knowledge viewed in this way is provisional and dynamic. Scientists are continually trying to change their knowledge by trying to prove it false. What we have just outlined are some of the basic assumptions and beliefs of fundamentalist religion and science.

Scientists will maintain that of all "the ways of knowing", science is the one that relies most heavily on reason and logic. I would argue, however, that every way of knowing employs logic. The difference in their conclusions usually lies not in their use of logic or their reasoning processes, but rather in the basic set of assumptions and beliefs (value premises) from which they begin their deductions.

History is a discipline which studies a branch or section of human knowledge. What are the basic sources of its knowledge (i.e. its epistemology) ? It relies on original documents, artifacts, records, and interviews with people who were there, among other sources, to build up its knowledge. It is difficult for its scholars to rely on repeated controlled experimentation, but to the extent that it does it may be considered scientific. Notice that knowledge in History is built up by humans and it is thus subject to human errors, such as bias and prejudice. Also notice that science,too, is a human way of knowing and thus subject to human errors. (Some scientists would have you believe otherwise).

There are almost as many " ways of knowing " about the world as there are areas of knowledge or disciplines. In fact, different sets of basic assumptions are often what distinguishes disciplines. Artists rely heavily on the work of other artists, art history, and art teachers as the authority from which they will build up their knowledge; economists rely on statistics, surveys, and past performance to try to advance economic theories to understand the economy and to advise politicians about fiscal and economic policy. Aboriginal peoples often rely on an "oral tradition" to formulate their sets of beliefs, especially where a written tradition was not strong. Since no one way of knowing or set of basic assumptions covers all knowledge, most people build up their " world view " by using a combination of "ways of knowing".

Science gains its knowledge by relying on observation and experimental evidence which is then made public, often through standardized reports in research journals. The validity of the knowledge rests on the replication of the findings by other scientists carrying on the same procedures. Science has a historic nature (i.e. standing on the shoulders of giants); an holistic nature, in that each of its branches is consistent with each other branch; and a unique nature, as its way of knowing is unique. Its methods lead to tentative, probabilistic knowledge, strongly supported by the best evidence available, but at the same time always open to revision and complete change. Finally, science is a human enterprise. What science believes about nuclear energy today, for example, is what its nuclear scientists collectively believe, a human consensus. It must be stated, however, that some people distinguish between ideal science, which they maintain is objective and amoral; and the scientists as human beings who practice science, by nature subjective and moral or immoral.

Philosophers studying epistemology would view all this as just scratching the surface. They are more interested in whether the world outside our minds is reality, or whether the images we see in our minds of the world outside, like a map, is reality. We'll leave that discussion and other problems to them.

In addition to filling the heads of students with facts, then, teachers should be stressing how those facts arise. How do we know them, and what are the basic assumptions underlying that knowing ? It goes without saying that good teachers will match the level of thinking required to the mental maturity of the students.
Science has changed the world and made it a better place to live in many ways and much of this has been due to its "way of knowing". However, a functional science course should leave students with the lasting impression that all science is theory, just waiting to be improved. This lesson in the authenticity of science will serve students much better than the thousands of facts usually offered, most of which fade from memory in an amazingly short time.

PART 8: THE NATURE OF SCIENCE: THE SCIENTIFIC METHOD AND SCIENTISM

In the conclusions of its extensive study of science teaching in the elementary and secondary schools of Canada, in which many science teachers in Saskatchewan took part, The Science Council of Canada (1984) drew a shocking conclusion. The conclusion was that the graduates of our schools possessed some knowledge of science, but were woefully ignorant of how that knowledge was gained, knowing little about the nature, methods and epistemology of science. One of the strongest recommendations of the study was that graduates from Canadian schools and science courses should have an authentic view of science. What is an authentic view of the nature of science ?

In his book About Science, Barry Barnes(1985) recognizes science today as well established as the dominant form of cognitive authority in all modern societies; what counts as empirical knowledge in these societies is very close to being what scientists and associated experts allow so to count. He attributes most of the wonders of the modern world to science (and technology).

Science plays a crucial part in modern history. As the source of ever more and more reliable knowledge it is a progressive, liberating force. It makes people better and better informed, more and more able freely to calculate the consequences of their own actions over an ever- increasing range of conditions and in relation to an ever-longer time scale.

On the other hand, Barnes recognizes science as not extending to the realm of morals, and questions its usefulness in the areas of human behavior and human choice. It would seem important that students in our schools learn about the strengths, weaknesses and limitations of this "dominant form of cognitive activity".

Most people associate science with a method. When asked about this method, many people regurgitate a series of steps they first encountered in some distant past, including Problem; Apparatus; Theory; Diagram; Procedure; Observations; Conclusions and Application. Today, however, this series of steps is regarded by most scientists as a form of reporting an experiment, rather than the scientific method.

Others associate the method of science with a version of the following steps: Identifying a Problem; Stating an Hypothesis; Formulating a Plan; Carrying out the Plan; Gathering Evidence; and Drawing Conclusions. While undoubtedly some science is carried on this way, many scholars in fields other than science also lay claim to this approach, labeling it the "problem solving" method. In fact, many scientists claim there is no single set of steps which could be called the scientific method, and that there are as many scientific methods as there are scientists.

Francis Bacon (1561- 1626) believed that he had made a lasting contribution to the pursuit of science and knowledge when he advanced his method of scientific induction. The essence of this so-called Baconian picture of the scientific method was that scientific studies in a particular field started with the open- minded accumulation of data, followed by the development of an hypotheses aimed at explaining or collecting the data, followed by the testing of this hypotheses by key experiments; if the hypotheses is verified, it then acquires the status of a scientific law, and becomes a permanent addition to the body of certain knowledge or ultimate truth. The key step is that by which the general statement(the hypothesis) is derived from individual observations(the original data)- the so- called process of scientific induction. Only statements of observable fact(it was claimed) or statements derived from such facts by the process of induction were scientific, and only such statements could be regarded as certain knowledge or ultimate truth.

Starting with the philosopher David Hume in the eighteenth century, the first doubts about the validity of Bacon's method were raised. Hume maintained that induction is logically inadmissible, since no general statement can ever be derived from a finite number of individual observations. That is, just because the sun has come up every morning for thousands of years, does not prove it will rise tomorrow. The probability may be high, but there is no certain knowledge.

Amazingly, it was this Baconian method that was the common form of the scientific method taken away from our schools according to the Science Council of Canada. The image of science left with graduates was patterned after the Baconian model, that science was an infallible, mechanical process, by which, if the steps were followed rigorously, certain knowledge and ultimate truth could be produced (almost by anyone).

Some extremists regard science as the new religion; others of similar ilk claim that if science doesn't have all the answers to our problems, it will in time. This kind of belief, which would extend the authority of science beyond its currently accepted bounds, is called scientism, and the arguments used to support them as "scientistic" arguments. A scientistic argument is one which involves an illegitimate appeal to science; a scientistic attitude is one which makes a fetish of science and wrongly treats it as the only possible form of understanding or way of knowing.

Without question, neither science courses nor teachers in our schools are consciously attempting to teach a non- authentic view of science. But listen to two Canadian science educators and philosophers, Nadeau and Desautels(1984): " By giving insufficient thought and attention to the nature of scientific knowledge and the conditions under which it has been developed, science teaching reinforces beliefs and myths that are inherent in scientistic ideology. We fear that students of science in the secondary school do not think about what they are studying and its nature. Students must learn not to be manipulated. In many cases, the students approach to science is being shaped not only by the presentation of some of the least controversial scientific findings, but by the superimposition on these few findings of an interpretation of scientific practice that portrays it as an activity above all possible suspicion".

In this series of articles, I have tried to make the point that our society regards science as one of the most important subjects to be studied in the schools. In this article, however, I call for caution. We must ensure that science teaching at the elementary and secondary school levels is based on the objective of instilling in the students a critical approach to scientific activity, as opposed to scientistic mythology. In this first article on the nature of science,we have opened the Pandora's box of science teaching; in the next article we shall try to close it.

PART 9: THE NATURE OF SCIENCE: A MODERN APPROACH

In part 8 of this series, which has as its aim the investigation of the role of science in the schools, we reported that the Science Council of Canada and others have discovered that graduates from our schools, for the most part, leaned toward a Baconian view of science. In this article we want to look at Karl Popper's remedy for the fallibility of Bacon's method of Induction, and to briefly consider Thomas Kuhn's idea that science is a social activity. These three interpretations of science (and there are others) should dispel the idea that science is a completed enterprise which is fully understood, another erroneous message often taken away by students from science courses.

Because science is one of the most powerful and productive "ways of knowing" used by humans, it follows that schools should be considering not only the rich heritage of scientific knowledge which is worth passing on from generation to generation, but of equal importance, how that knowledge has been discovered. We call this an authentic view of science.

The method of Francis Bacon maintained that if we discovered, for example, that copper expanded when heated and contracted when it cooled, and so did iron and aluminum, and eventually liquids and even gases, we could reason from the many particular examples to the generalization that " all matter expands when heated and contracts when cooled". This method of logical reasoning is called induction and if its conclusion were supported by all examples we could observe, the statement would be elevated to become a scientific principle or law. Bacon believed that he had discovered the foolproof method- that if we mechanically followed the set of steps of his method of induction, the result would be ultimate truth. The philosopher Hume pointed out the logical fallacy in Bacon's method . leading to its demise. Hume said that a thousand examples supporting the generalization does not prove it correct, for the next example may disprove it. Thus, today induction is regarded as a useful tool for discovering probable generalizations, but not for proving them beyond doubt.

One representative modern approach to understanding the method of science, and to resolving the logical fallacy of Bacon, is found in the work of Karl Popper, born in Vienna in 1902. Popper maintained that although it is logically impossible to demonstrate that a scientific law is universally true by Bacon's induction, such a law can be disproved by a single properly- authenticated observation that does not fit in with its predictions. In other words, scientific laws should be tested not by attempting to prove them right, but by attempting (in the most rigorous manner possible) to prove them wrong.

An immediate consequence of Popper's reversal of the traditional approach to scientific method was that scientific laws lost their special status as certain knowledge, and became merely "working hypotheses" to be retained only as long as they continue to agree with our observations. As soon as the law (or generalization) fails to do so, it should be discarded and replaced by a new law that fits all the facts that are currently available. Thus, scientific laws are always temporary, tentative phenomena, inevitably to be superseded by more powerful laws, just as Newton's Law of Universal Gravitation after many years of viability was eventually replaced by Einstein's General Theory of Relativity.

According to Popper, then, science starts with the significant achievement of identifying a problem and proposing a trial hypothesis or theory as a solution to the problem. Note that in opposition to the mechanical nature of Bacon's steps, Popper regards all science activity as creative and imaginative. Next, the theory is subjected to a rigorous process of attempted. falsification by using the theory to make predictions and then experimentally checking these predictions. The three possible outcomes of this testing are incompatibility or agreement with the theory, or findings leading to modification of the theory. When the Science Council of Canada calls for more authentic views of science, it is calling for something like Popper's model to be taught in our schools. Bacon's induction may still retain its status as a powerful tool for discovering and supporting generalizations, but not for proving them beyond doubt.

In addition, most modern scientists and science historians give a place in our schools to the view of scientific progress advanced by Thomas Kuhn, an American who published his ideas in 1962.

Although his ideas are somewhat more complex than we can do justice to here, Kuhn advanced the theory that progress in science through history has been made through what he called " scientific revolutions". Suppose, for example.(as was actually the case historically), one group of scientists believed that light was by nature a particle. This group would carry on what Kuhn called "normal science" by doing research to better understand the particle model of light, publish results and report them to science conferences, write texts, and inculcate budding young scientists with their theories. This process would continue until an error or anomaly would be discovered in the particle model. Historically, for example, the particle model could not explain interference of light. Since the basis of all the research using the particle model was now questioned and a crisis situation exists, confusion reigns in the scientific community of scholars who believed in the particle theory of light and a frantic search begins for a modified model or new model to replace the old model. Kuhn calls this new activity " extraordinary science" and the whole process of abandoning the old model for a new one which better fits the facts, a "scientific revolution". Historically, the new model which could explain interference of light regarded light as a wave. A new group of scholars embraced this new model, and Kuhn's "normal science" begins again.

The major message for schools from Kuhn' s interpretation is that science is a sociologically- oriented activity. Scientific methods and norms of a universal nature were unnecessary and replaced by the authority of groups of scientists of a common mind about a major theory or model which describes and explains observations. What the scientific world and the general public were asked to believe about nuclear physics, as an example, is what the group of scholars called nuclear physicists collectively and in consensus believe. Science is a human and social activity. Science teachers serve not only as purveyors of a store of theoretical knowledge, but as a means through which scientific activities are legitimized and given value.

As part of a society which has given science an extremely important position in its school programs, we should insist that an authentic nature of science be taught. The teachings of Bacon, Popper, and Kuhn should be given an important place in our science courses.

PART 10: THE COMMON ESSENTIAL LEARNINGS IN SCIENCE

Science, like any other area of study in our schools, should be subject to periodic revision. As a result of the recommendations of the Directions and Core Curriculum reports in Saskatchewan, all the subject areas in our schools will undergo re- writing following a sequential 10- year implementation plan conceptualized by Saskatchewan Education and starting with elementary science in 1990.

One of the main reasons for wholesale revision is the adoption by SaskEd of the recommendation by the Core Curriculum committee that the Common Essential Learnings (CELs) be an integral part of every subject taught in the schools. The obligation of professional teachers, then, is that they not only teach their special subject, but that they also take advantage of every opportunity to develop the CELs while they are teaching that subject. Every teacher becomes a CELs teacher.

The CELs are Communications; Numeracy; Technological Literacy; Creative and Critical Thinking; Independent Learning; and Personal and Social Values and Skills. These Essential Learnings have been carefully defined and every new curriculum guide will incorporate for teachers strategies of how to integrate them into each subject area.

In addition, you will remember, in science, a shift in emphasis has also been made from teaching mainly content, to teaching content and how that content may be used by students in everyday life. That utility has been encompassed in what is called scientific literacy, which was the subject of Part 5 of this series. In this article, we would like to consider several examples spread over many grades of how the CELs could be incorporated in the new science program; in particular, how could the science teacher use science experiences to contribute to the general education of the students by promoting the Common Essential Learnings in a deliberate, formal way.

1. Communications. In the Grade One Core Science Unit on Animals, students carry out activities in which they learn to recognize characteristics which may be used to identify, describe and classify

animals. What follows are three examples of how teachers might combine student work in science with Communication skills. (i) Students are asked to express themselves orally by describing their pets. (ii) Students are asked to compare common pets with more exotic animals of the same family to help them mentally organize. (iii) Students may print the new vocabulary they have learned in a sentence, if they have developed that capability.

2. Numeracy. In Grade Twelve Physics, students study the basic principles of electrical energy involving circuitry and measurements such as kilowatt hours. To contribute to CELs(i.e. numerical literacy skills in this case), the students are given the following assignments: (i) A graph of electrical consumption for winter months taken from the local newspaper is thoroughly interpreted. (ii) Students are asked to calculate electric power bills based on the rate in their community. (iii) Students do a project in which they estimate future energy costs, consider sources of future energy needs, and reconcile environmental concerns.

3. Technological Literacy. One of the Core Units in the new Grade Six Science program is entitled Exploring Space. As part of this unit students study how satellites, space probes and rockets have been used. Three of the many dimensions of Technological Literacy may be developed in the following exercises. (i) To recognize the impact of technology on human lifestyle, the students study the spinoff devices from the space program. (ii) To understand the interaction between society and technology, students study the economics, risks and benefits of the Canadian space program. (iii) To consider values and technology, students study what alternatives could be developed with the money spent on space research.

4. Creative and Critical Thinking. Three of the many elements which compose this CEL are found in the following objectives. (i) Creates original designs and descriptions. (ii) Analyses information, events, and situations. (iii) Distinguishes between fact and opinion. In Grade Seven Science students will study Energy in the new program. In contributing to the development of the student's creative and critical thinking skills, the science teacher may have the students imagine new means of producing and harnessing wind, solar and tidal energy; analyze the events surrounding the Alameda and Rafferty Dam projects; and, try to separate fact from opinion in newspaper articles on the Dam project.

5. Independent Learning. Grade Four Science students study a Core Unit on Science and Rocks, a topic particularly useful for Northern Saskatchewan. Science teachers could cultivate Independent Learning skills and abilities in their students while studying this topic by having them discover for themselves rock stratification and possible fossil deposits during a field trip . Students could be asked to write a project time line for their own rock and mineral collections focusing on research into identification and origin. A third exercise might involve collecting information on the Canadian Shield from a variety of sources.

6. Personal and Social Skills and Values. High school Biology students study Human Biology. Teachers may use this study to assist students in cultivating Personal and Social Skills and Values. Cooperative Learning techniques may be used to study Nutrition, for example. Students may develop insight into the beliefs, values, attitudes, assumptions, and motives of others by studying Cultures, a topic which would integrate other subjects as well, such as Social Studies.

Curriculum developers in Saskatchewan have identified six groups of essential learnings which they believe should permeate everything students study in schools. The policy of incorporating these CELs, plus other considerations, has necessitated a total revision of all curriculum materials used in the province. In this article, we have looked at how science teachers may make their subject more relevant to students. Of course, it should be recognized that exemplary teachers have always been successful in assisting students to realize how what they are studying fits into the big picture.

PART 11: SCIENCE AS A PROFESSION

Students in our schools today, even those who are considering science as a career, are rarely exposed to dimensions and characteristics of the profession of scientist. Most scientists work in research, either pure or society- related (often called mission-oriented) at universities or in industry. But what do they do, how have they established themselves historically and how do they impact on society ? In this article, I would like to consider some of these dimensions.

If we were to eavesdrop on the conversation between a child and his or her scientist parent, it might go something like this. " What do you do as a scientist ?" The scientist parent replies, "My job is to try to change knowledge. To try to change what people know. My work is usually limited to certain fields like the natural environment, but this has been expanding. Every morning when I go to work, my aim is to try to find out something new which we didn't know before. With scientists around, the world's knowledge will be continually changing for the better. That is what we do". Imagine having a job the main task of which is to modify or expand knowledge and getting paid for it !

In his recent visit to Saskatoon, an apologist for Atomic Energy of Canada Ltd. shocked the audience by declaring that "God is a nuke !" Frank Finley, as reported in the Star- Phoenix, went on to explain what he meant. " Radiation wasn't invented (by scientists), it was discovered, and is as old as the earth. Uranium is a gift to be used or abused. Good old radiation is not evil. If it's made evil don't blame the nuclear industry." This report highlights another dimension with which scientists, technologists, and indeed, all inventors and creators must live: should they be blamed if people use their discoveries for negative or evil purposes or if, as well as benefits, their discoveries may cause harm ? Should we abandon the benefits of new discoveries simply because society, politicians, the military, tyrants, or the average citizen misuse or abuse them ? Should we abandon the use of fire because in some relatively rare or accidental instances it damages and takes lifes ?

Some people, among them some sociologists, blame science and technology for all or most of the ills of society and the environment today. The irony of this position is that without science and technology, these people would not know there was a problem: they would not have the skills to measure acid rain, the greenhouse effect, and the pollution of the air and water, and would not know about pollution. Further, when society looks for cures to these maladies, it relies on the advice of these same scientists and technologists. Some claim that the world is a far better place in which to live today, with a much higher standard of living, because of science and technology, while others blame scientific and technological advances for unemployment and other similar social problems.

What has been said in this article thus far suggests elements of a serious issue which our present and future society must attempt to resolve: what is the role of science as a profession in the society of the twenty- first century ?. And surely, if such a resolution will have a profound impact on the society of the future, the issue should be an important part of the school science studies of students who will determine and live that future.

In his fascinating book About Science, Barry Barnes (1985) presents a number of observations related to science as a profession- or institutionalized science- that would be worth pursuing at an appropriate level in school science curriculums. A sample of such observations from Barnes and other sources follows.

1. Scientists did not inherit their recognition as cognitive authorities; they actually went out and fought for it, particularly establishing bases and training grounds in educational institutions. Our society grants science and scientific knowledge the place which our predecessors allowed priests and religious doctrines.

2. Since the role of science is to extend and modify knowledge as a matter of routine, science forces our society to live and contend with a marvellously potent knowledge- changing- device more or less permanently implanted as part of our system of institutions. As science emerges and evolves as a social institution, how may society deal with it ? The enduring legacy of the nineteenth century - when modern science arose- is the permanent problem of the use and control of institutionalized science.

3. Scientists have established unique practices and arrangements which bind their professionals together and make them successful.

They have similar prolonged and intensive training. Scientists share standardized procedures for communicating, evaluating work and learning from others. These procedures are made manifest through publishing in journals and presentations at conferences. Scientists are motivated by the desire for recognition, which is the route to all things in science. Recognition serves the dual purpose of reward and incentive.

4. Scientists have devised a means of perpetuating themselves mainly through colleges and universities. Science curriculum is presented by its teachers with authority. Ironically, scientific training is authorative and quasi- dogmatic, and scientists tend to be a conservative group, not changing their opinions easily.

5. Scientific knowledge is convincing because scientists acquire a craft, made up of how to do science (procedural knowledge) validated by doing it. However, no set of observations and results accumulated by scientists can ever suffice conclusively to establish a theory, since however hard scientists work, the data they generate are always finite. Nevertheless, even though scientific knowledge is theoretical and tentative, since it is supported by the best evidence available through extensive testing, it is eminently useable.

6. It is generally accepted that society need not fear a takeover by science, what is generally called Technocracy, because most scientists are not interested in becoming politicians, are too specialized in knowledge, and have difficulty agreeing among each other on many matters. Although science is a part of every aspect of society- including the military- industrial complex- the role of scientists is usually advisory, and it is rarely in control. The expression used to describe this situation is to say scientists are "on tap but not on top". Science provides some of the facts and empirical inferences relevant to society's decisions and judgements.

The hodgepodge of this article is analogous to the hodgepodge of concerns and issues surrounding current science and scientists. Nevertheless, since science plays such an important role in modern society, the study of the potpourri of science as a profession should be of great worth to future citizens.

PART 12: THE SCIENCE BACKGROUND OF STUDENTS FROM NORTHERN SECONDARY SCHOOLS

When the science profiles of the graduates of secondary schools in northern Saskatchewan are considered there is good news and bad news. The bad news is that the percentage of Native and northern students graduating with grade 12 science credits is far below that for southern schools and the provincial average; the good news is that over the last ten to fifteen years the picture has been slowly, but inexorably, improving.

Job openings and empowerment in the north are closely related to science prerequisites. A recent newspaper article, as one example, describes ten of the colleges at the University of Saskatchewan having entrance requirements skewed in favor of mathematics and the sciences.

Although this article will deal primarily with the future of the graduates from the secondary schools in the north and how this future is determined, at least in part, by their science credits, my position is that northern schools must provide adequate science programs for all students, the early- leavers as well as the graduates. In addition, the science programs in the schools must prepare students for a variety of futures in society, not just post-secondary education. The fact remains, however, that a certain proportion of students which graduate from secondary school do go on to seek higher education and therefore one of the tasks of the schools of the north is to offer science courses which prepare that group of students for higher education.

A survey of institutions offering advanced schooling beyond grade 12 leads us to the conclusion that Natives and northerners are still under- represented in science- related occupations, mainly because of their weak science background.

Among the courses offered by Northlands College are a Chemical Lab Technician course in La Ronge accredited by SIAST, and an Integrated Resource Management course at Buffalo Narrows. In the former, a grade 12 with Algebra and Chemistry are preferred, and in the latter Biology and Chemistry are desirable. According to Randy Johns, General Counsellor at the La Ronge program centre, they always have a difficult time finding fully qualified applicants because of the trend for students to opt out of high school science courses. They have attempted to add.ess this by offering a 3- month upgrading course for Chemistry and Algebra. He does report, however, that present high school grads do have slightly improved science backgrounds.

Don Bird, Community Relations Coordinator for Cameco in La Ronge, admits Cameco, Amok, Denison, Minatco and other mine operators are beginning to feel a sense of desperation as they attempt to meet their goal of 50 % northern workers in all of their operations by 1995. They simply cannot find qualified people, and science background continues to be a problem. In spite of Mine- Mill worker programs, scholarships for technical advancement, programs such as the Athabasca Innovations Project, in- house advancement programs and others offered by Cameco and other operators, insufficient numbers of northerners are being found for the jobs. A Cameco report in September, 1990, admittedly only one case, illustrates that the higher the scientific- technological qualifications required, the smaller the percentages of northerners on the job. For Cameco's Key Lake, Rabbit Lake, and Jasper operations, the percentages of northerners employed related to the total employees are labourers 100 %; mill operators 70 %; heavy equipment operators 49 %; trades 19 %; technical 23 %; and supervisory 9 %.

The University of Saskatchewan delegated Ms. Gerri Dickson and Dr. James Irvine to study the area of enhancing native people's access to the health- care profession's education at the University. In their report " Native Access to the Health Professions" released in May, 1989, they stated that Native people are markedly under-represented in the health professions in Canada and recommended that health professionals sharing cultural roots with the general native population of Saskatchewan would be valuable assets in improving both health- care delivery and health promotion. They confirmed a finding of the Manitoba Professional Health Program that Native students have the most difficulty dealing with the early, science- laden years often due to a weak background, although they may later excel in the clinical area.

Institutions which continue to play an important role in the future of science education in the north are the Northern Teacher Education Program(NORTEP), the Northern Lights School Division, SaskEd, and the Tribal Councils and Band schools. The beginnings of providing a strong program and cultivating an interest in science is in the hands of elementary teachers and parents. With the advent of a new elementary science program in the schools in 1990- 91 and revision of middle and secondary science programs in the next few years, an unprecedented opportunity exists to rebuild the foundations of science education. Teachers should realize that subjects like science(and social studies, arts education, and others) may complement and supplement the typical strong emphasis on language arts in a highly positive manner, broadening knowledge, vocabulary and interest. Secondary schools must provide interesting and relevant science and technology programs for all students. If students do not wish to take more academic science, schools may offer school- leaving courses, and just recently credits in science with an 18 number for Alternate programs have been approved at the provincial level. The bottom line to all this is that science is important for the north !

In the north's largest school system, the Northern Lights School Division(NL), enrolment from grades K to 12 over the last ten years has always settled between a low of 4344 students in 1981 and a high of 4516 in 1987, a very stable total. However, the total enrolments in grades 11 and 12 has gradually increased. The average yearly enrolment in the 3- year period from 1980 to 1982 was 66 in grade 11 and 44 in grade 12. Compared with this, the average yearly enrolment in the 3- year period from 1988 to 1990 was 149 in grade 11 and 107 in grade 12. Northern students are also electing to remain in high school in their home communities more frequently, the number attending high schools in the south (such as Carleton and St. Marys in Prince Albert) and supported by Northern Lights, decreasing from several hundred earlier to 50 in 1985, and only 8 in 1990, according to Don Shinske, Coordinator of Student Services for NL.

Information on graduates from secondary schools in NL was sought from the Provincial Examinations and Student Records Branch of Saskatchewan Education. Assuming these data are accurate, the number of students which completed grade 12 in NL schools was 48 in 1988; 69 in 1989; and 66 in 1990. Schools having grade 12 graduates were, La Ronge Churchill, the largest number; Dene in La Loche; Kistapiskaw in Deschambault Lake; St. Pascal in Green Lake; Twin Lakes in Buffalo Narrows; Valley View in Beauval; and Charlebois in Cumberland House (for the first time in 1989). Over the three year period 79 students completed Chem 30; 46 completed

Physics 30; and 199 students gained credit in one of the two grade 12 Biology courses. These science figures are very low compared with provincial averages, but at least they represent a slow gradual increase. Director Dennis Lokinger indicates that the NL board has a strong commitment toward offering broad science programs in the high schools.

The picture painted for NL schools is a mirror image of the situation found in the band schools of the Prince Albert Tribal Council(PATC). This means that an increasing number of band schools are offering grade 12 programs, more students are graduating from grade 12, fewer students are being supported in schools outside of the northern communities, such as St. Mary's and Carleton in Prince Albert, and more students are including the sciences in their grade 12 programs. All this is confirmed by John Stobbe, Education Coordinator for the PATC, who cautions that this is a slow change and that some schools have difficulty offering all three sciences each year. All the band schools in Saskatchewan use the same curriculums as other high schools. Tim Goddard, Superintendent of Education for the Lac La Ronge Indian Band, maintains that if the bands are to become involved in economic development, mines, industrial development, skilled positions, and management, they have to have people qualified in science. Science is required for getting ahead. Goddard says the La Ronge band is proud of the science lab planned for the new secondary school at Kitsaki reserve to be started later this year. Ted Green at Stanley Mission, and Ida Swan at Pelican Narrows, principals of band schools with almost exclusive Native enrolments, attest to the greater current student interest in both science credits and post- secondary education.

Teacher education plays an important role in the future of science education; elementary teachers with some background in, and a positive attitude toward, science encourage their students to take a lifelong interest in science. The north often has difficulty attracting teachers who are qualified in science. Of course, this is also a problem in the smaller schools of southern Saskatchewan.

One of the professions which has done a superior job of opening it's doors to Natives and northerners in the last 15- 20 years is the teaching profession, especially through teacher education programs (TEPs) known as ITEP, NORTEP and SUNTEP. These programs have had remarkable success by requiring students to satisfy all the usual requirements for the B.Ed. degree, but allowing them to take longer if necessary; providing upgrading courses; and offering support services in centres, most located off the Regina and Saskatoon campuses. Joan Poole, a NORTEP instructor, reports that in the 10 years that Nortep has existed in La Ronge, 133 northern students have graduated with a B.Ed. and the background of students entering the academic program has gradually improved so that at this time about two thirds have grade 12 and one third enter under Mature Admissions. Incidently, teachers with a native background now make up 25 % of the staff of NL, while 85 % of the students in NL have a native background. University students at NORTEP almost always have Biology as their high school science and almost always take Biology as the science credit in their degree program. Recently, NORTEP has moved into a B.Ed. secondary program and hopes to attract northerners who will major in science.

While enlarged communities in the north have meant larger secondary schools with the attendant capacity to offer more subjects including science, additional innovative approaches are also being attempted. This year students in Green Lake, Beauval, Buffalo Narrows and La Loche have studied Physics 20 and 30 through a Distance Education experiment funded by SaskEd through Northern Task Force money. In 1991- 92 physics will probably become a regular part of the offerings of these westside schools, while it is planned to make other subjects available through Distance Education.

The future of science education in the north may be regarded with optimism, although it is obvious much more work needs to be done to empower northerners to take their rightful place in controling their own futures. School science is one of the keys to that future. The creation of complete science programs is taking time and requiring patience. Some good programs now exist and the system is building on these. New programs are being created in response to the needs of the changing north.

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