M.Ed. Thesis

TEACHERS PERSPECTIVES ON THE IMPLEMENTATION OF THE ONTARIO ELEMENTARY SCHOOL SCIENCE CURRICULUM

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ABSTRACT

This study examined the implementation of the Ontario elementary school Science and Technology curriculum from the perspective of nine grade 8 teachers of varying experience and specialization. The questions which this research attempted to address dealt with the teachers' knowledge of the implementation process and their knowledge of, adaptations to and challenges with the introduction of the current science curriculum. Included in the study are questions concerning the changes teachers have made in the means of instruction with specific emphasis on the inquiry and design method, as well as the changes teachers have made in assessing/evaluating student achievement.

This research was a preliminary, investigative, applied type research which began when the implementation process was only in its first year. The qualitative research method of case study using standardized, open-ended questions was used. Data analysis involved the organization of the data into categories and subcategories. Inductive analysis was used to determine themes, patterns and relationships in the data.

Most science teachers have a substantial knowledge of the curriculum (its content and nature) and feel that in order to cover the extensive, structured, and challenging curriculum they need to accept it, integrate it, look to each other for support, and re-evaluate continually.

Teachers' perceptions of their ability to teach science is a major contributor to effective science curriculum implementation. The majority (six) of the teachers felt that having a science background (general knowledge of big science ideas) or being qualified in science would assist in implementation of the new curriculum, and the findings from this study showed that most of the teachers were knowledgeable about the new curriculum, and were implementing it with little difficulty.

A major inhibitor to the effective implementation of the science curriculum was lack of resources: resources to help teachers to implement their lessons, their labs (materials and space), and their assessments and evaluations. Most teachers' expectations for the future include more in-service/PD, teacher resources, equipment, and textbooks.

The factors identified in this study as contributors to or inhibitors of the effective implementation of the science curriculum included the time intensive and complex nature of the curriculum, the ability of the teacher to understand and deliver the curriculum with emphasis on instructional and evaluation practices, and the availability of resources. In addition the assistance and guidance received from administration and the professional development provided to the teacher which affects the school culture are also identified as contributors or inhibitors to the effective implementation of the science curriculum.

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Finally, I dedicate this thesis to my husband, Dr. David Cooper, for with his constant understanding and support I was able to finally complete this thesis.

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1 INTRODUCTION

1.1 Background

In the 1998-1999 school year a new science curriculum was implemented in the elementary schools in Ontario. This curriculum places much emphasis on the development of science and technology concepts through inquiry and design, and the use of performance based methods of assessing student achievement.

1.2 Personal Ground

I am a full-time high school teacher with 7½ years teaching experience in science and mathematics. I am a part-time Master's of Education student presently working towards my thesis requirements. I have a Ph.D. in Chemical Engineering and thus an extensive background in science. Although I am now a full-time mathematics teacher, when the proposal for this work was written I was a full time science teacher so that in addition to my general interest in science education, the implementation of the new science curriculum in the elementary schools would have had a direct impact on my teaching career as a secondary school science teacher. Even though I no longer teach science, because of my science background I remain interested in science education. One of my interests in science education is in the development of scientific methodology and knowledge at all levels of education. I firmly believe that students need to construct their own knowledge for it to be meaningful to them, that students need to develop skills in answering questions and solving scientific/technological problems, that students should be encouraged to develop their thinking process, that students should be involved in doing many science and technology activities-investigating, exploring, and experimenting and designing, and that students relate science and technology to each other and to the world around them. Some of the attitudes that I feel are important are a constant thirst for knowledge and understanding, being aware of biases, respecting the environment, and having a sense of curiosity.

1.3 The Purpose of the Study

The questions which this research attempted to address dealt with the teachers' knowledge of the implementation process and their knowledge of, adaptations to and experiences with the introduction of the current elementary school Science and Technology Curriculum *(The Ontario Curriculum Grades 1-8: Science and Technology*, Ministry of Education and Training, 1998b). Particular emphasis was placed on examining how teachers were developing science and technology concepts through inquiry and design, and the methods teachers were using to assess student achievement. The four major questions addressed by this study are:

1. What knowledge do teachers have of the implementation process?
2. What knowledge do teachers have of the new curriculum?
3. What changes have teachers had to make in order to adapt to the new curriculum?
4. What challenges has the new curriculum posed and what solutions have teachers found for these challenges?

1.4 Significance

For curriculum implementation to be successful it has to be successfully implemented by teachers in the classroom. I therefore focus on the teachers in this study - their knowledge of, adaptations to, and challenges and solutions found during the implementation process . This research focuses on the implementation of the science and technology curriculum by Grade 8 teachers in the elementary schools. It is hoped that this study will provide direction to schools and the school boards involved so that inservice implementation activities can be oriented to areas of teacher concern.

1.5 Limitations

The following points constituted the limitations of this study:

1. At the time this study was done, some teachers were in their first year and others in their second year of the implementation process so that teachers' perceptions were not fully developed.
2. The short time over which data was collected did not provide much information on the evolution of the implementation process as the data collection process averaged approximately one month in the first year and two months in the second year.
3. The validity of the data is dependent on the subjects' honesty.
4. The number of teachers used in this sample is small so may not be representative of the population.
5. The purposeful selection of the sample may not allow for generalizability.
6. The small number of elementary schools and science specialists limited the size of the pool for sampling.
7. The standardized open-ended interview did not allow for flexibility in questioning.

1.6 Outline of the Study

This study is divided into five chapters. The first chapter introduces the study, the nature of my personal interest, its purpose, limitations and significance.

Chapter Two reviews related literature. The history of science education in Ontario is briefly summarized, recent research on the science curriculum and the development the Common Framework of Science and Learning Outcomes, K-12 are discussed. In the second part of this chapter current concepts on the implementation process are discussed, *The Ontario Curriculum Grades 1-8: Science and Technology* is outlined and where the process stood at the time of the study is described.

Chapter Three explains the methodology followed in this study, the design of the study, the type of sampling, type of research, types of questions, ethical concerns, data collection and analysis are discussed.

Chapter Four presents the interview data and the findings of the study. Themes in the responses to each question in the interviews are identified, typical responses quoted, and the results summarized

Chapter Five summarizes the themes, patterns and relationships relating to the major research questions found in the study. Recommendations and suggestions for further research are made.

2 LITERATURE REVIEW

2.1 Science Education

2.1.A A Brief Historic Summary: Science Education in the Ontario School System

By the beginning of the 20th century, science was firmly established as a legitimate subject at the university and secondary school levels. There were two basic areas of science: one included the study of science as it related to practical subjects such as agriculture, household science, and technical studies; the other included the study of scientific disciplines as preparation for science-related professions such as medicine and engineering. The Industrial Training Act firmly connected science to education and education to the world of economics.

The following history of Science Education in Ontario since 1950 is primarily a summary of that presented by Connelly (1987, p. 7,8). Since 1950, the government has emphasised the recognition of individual differences among students and has supported educational services within the local community to accommodate these differences. The Ministry of Education developed organizational and administrative structures and processes to support a decentralized system of educational services. During the 1950's, an emphasis on preparation for citizenship, work, and post-secondary education was added to the existing foci of literacy and numeracy. The development of the primary, junior, intermediate and senior divisions within the school system reflected emerging ideas about the intellectual, emotional and social development of children. Science was a compulsory subject up to Grade 10 with general science being taught in urban schools and agricultural science in rural schools.

The post-war baby boom and immigration brought about a shortage of teachers in the 1950's. An emergency program brought in many new teachers, some having professional experience in the applied sciences. By the end of the decade a major focus in science had become space exploration, with the associated demand for greater excellence in related academic studies, particularly physics, chemistry and mathematics. In the 1960's, in response to new science programs in the United States and Britain, science programs based on the US and British models were introduced on Canada. These changes were the result of governmental concerns, at both federal and provincial levels, about the quality and quantity of skilled manpower required for an increasingly technological workplace. As a consequence of this, the Vocational Training Act made the development of educational programs and creation of necessary facilities and resources at the secondary level a national priority. Science received extensive attention during the 1960's. New curriculum guidelines, based on inquiry and experimental methodologies, were designed and implemented in all science disciplines. By the end of the decade an emphasis on environmental concepts, relationships between living and non-living things, between humans and their social and physical environments had lead to changes in science related studies in the Primary and Junior Divisions (Connelly, 1987, Keeves & Aikenhead, 1995).

During the 1970's, there was an increased push towards decentralization of the educational system. A credit system was introduced to allow local schools to accommodate the differing needs of individual students. Local schools and teachers were encouraged to develop and use experimental courses in science. Various attempts were made to revise Intermediate Science and Environmental Science guidelines with limited success. At the decades end concern was focused on academic excellence, declining enrolments and economic restraints, and the effects these would have on science education, namely increasing class size and decreasing availability of science materials (Connelly, 1987).

In the 1980's compulsory credits returned. There was an increased emphasis on basic knowledge and skills in communication and mathematics, on being technologically literate, on being better prepared for the world of work, on understanding the nature of Canadian society and culture, on basic skills and attitudes about physical and mental well-being, and on new ways of educating and continuing the education of teachers. Two credits in science of 30 credits were required for an Ontario Secondary School diploma (Ministry of Education, 1982). Three directions of Ministry policy affected science education:

1.) to encourage the use of computers in the classroom,
2.) to ensure the provision of adequate services for students with special educational needs within local rather than segregated schools and
3.) to extend the French-language rights.

2.1.B Research on the Science Curriculum

Various studies have been done on the science curriculum - provincially, nationally, and internationally. Some of the research is theory oriented, while other studies examine the effectiveness and quality of science education aiming to improve science education in Ontario and Canada. Information for research on the aims and objectives of science programs is complicated because the response to questions about them depends on the person asked. The International Association for the Evaluation of Educational Achievement (IEA) structure for classification of curriculum is captured by three terms: the intended, translated (taught) and the achieved (learned) curriculum. According to Rosier and Couper (1981) these are defined as follows:

> The *intended curriculum* may consist of a detailed specification of content and processes or it may consist of more general guidelines. It is often directly associated with an explicit set of aims underlying the curriculum. It may include suggestions about methods of teaching the curriculum.
>
> The most ambitious or thorough intended curriculum issued by educational authorities will have little effect on the education of students unless effectively translated into meaningful learning experiences by science teachers. This occurs at the level of the individual science classroom - the *taught curriculum.*
>
> The achieved curriculum indicates the extent to which individual students internalize the experiences that were planned and organized for them. This means, for example, that the students learn the content as described in the intended curriculum, that they develop competence in the specific practical and investigative skills, and that they adopt the intended attitudes - the *learned curriculum.*

Ideally, research at all levels would yield identical information; however, this is never the case because of a variety of variables such as the type of sample (provincial, national, international), and size of the sample (is the sample sufficiently large to be representative?).

Connelly (1987) found more than 50 studies in Ontario directly connected to science education. In addition, other studies which also include Canadian and international studies have a very broad sweep and scope as found in the following paragraphs. Most focus on Ontario and on some sub-set of problems within science education. A number of these studies were commissioned by the Ontario Ministry of Education and Training, and still others were done by specific boards of education. As Connelly states "Given the fact that there are 10 faculties of education in the province, all with professors of science education, the level of research is modest" (p. 9). Some of the work is theory-oriented and is not aimed at the influence of practice, other reports are curriculum development reports.

Major initiatives and studies in science education where large quantities of data were collected included the following:

1. Science for Every Student. Report 36, Science Council of Canada

The Science Council of Canada (SCC) research program in 1984 included the examination of science curriculum guidelines in each province and territory, an analysis of 30 commonly used science textbooks, a survey of teacher opinion and eight case studies of science teaching in schools in various parts of the country. The results of this research were published as a three-volume background study, *Science Education in Canadian Schools* (Orpwood & Souque, 1984). The SCC report discussed the need for Canadian citizens attaining a good working knowledge of science concepts that they could apply to the world around them and inquiry skills. The SCC (1984) also believe that science education programs would:

• develop citizens able to participate fully in the political and social choices facing a technological society

• train those with special interest in science and technology fields for further study

• provide an appropriate preparation for the modern world

• stimulate intellectual and moral growth to help students develop into rational, autonomous individuals (Council of Ministers of Education Canada, 1996, p. 6)

2. IEA/SISS Study of Science Achievement

In 1980, Canada participated in a 4 year study, one of the largest ever international curriculum studies, the Second International Science Study (SISS) under the International Association for the Evaluation of Educational Achievement (IEA). Forty countries were initially involved, and 25 of them, including Canada, completed the study. The general purposes of the research are best seen in the goal statements prepared by IEA/SISS (Keeves & Rosier, 1981) and by IEA/SISS Canada. Some of the more important aims of Canada's participation included the following:

• to compare Canadian science curriculum policy with science curriculum practice and generate knowledge of the relationship of policy to practice.

• to influence and participate in world trends in science education and science education research.

• to integrate this knowledge with the results of the Science Council of Canada Study, thereby providing a knowledge base of policy and practices unparalleled in any other area of the Canadian curriculum.

• to establish a solid descriptive basis for further empirical, experimental and ethnographic research in science education in Canada.(Connelly, 1987, p.3)

The Ontario Ministry of Education used the data generated in the study as a vehicle for assessing science education in the province, and comparing the province to the rest of Canada. In general, it was found that Ontario students had positive attitudes about school and science, but their achievement was not as high as might be expected in the richest province in Canada. In addition, Ontario had shown innovation in curriculum decision making and exhibited more confidence in its local personnel than the other provinces. The book *Science Education in Canada: Volume 1. Policies, Practices, & Perceptions* (Connelly, Crocker, & Kass, 1985) summarizes these research findings.

3. Report on Science Assessment, School Achievement Indicators Program (SAIP) Canada, 1996, 1999

The School Achievement Indicators Program (SAIP) is a pan-Canadian initiative of the Council of Ministers of Education, Canada (CMEC). Through CMEC, established in 1967, ministers can take action in the national interest, with respect to the effectiveness and quality of the educational systems of Canada, specifically in the assessment of the achievement of students in the areas of reading, writing and science. The information collected through SAIP is to be used by each province and territory to plan educational program improvements. SAIP's aims for science include developing in the student their knowledge of science, and the skills of inquiry and design, as well as showing students the inter-relationships between science, technology and societal issues.

Science testing was administered in 1996 and 1999. The 1996 and the 1999 assessment (CMEC, 1996, 1999) were designed to examine the achievement levels of 13- and 16-year old students in science. However, by 1999, in addition to the question "How well have Canadian 13- and 16-year old students learned science in 1999?", CMEC also wanted answers to the question "Has the achievement of Canadian 13- and 16-year old students in science changed since 1996?".

The 1996 assessment was administered to 37000 13- and 16-year old students across Canada. The results from this assessment are highlights of a few findings in Canada and in Ontario (CMEC, 1996, ¶ 1)

• There was a significant difference between the achievement of 13- and 16-year old students in both the written and practical task components. More 16-year-olds than 13-year-olds attained level 3 or above. (Canada)

• Both in the written test and practical task, the majority of students achieved results at level 3 on a 5 level scale. (Canada)

• In the written component, Ontario (English) 13- and 16-year olds performed slightly less well than Canadian students as a whole. (Ontario)

• In the practical task component, Ontario (English) 13- and 16-year olds performed as well as Canadian students as a whole. (Ontario)

• Among both age groups in the assessment, girls were found to possess as many science inquiry and problem-solving skills as do boys of the same age

The 1999 assessment was administered to 31 000 13- and 16-year old students across Canada. The results from this assessment are highlights of a few findings in Canada and in Ontario (CMEC, 1999, p. 97)

• Results show that, for Canada as a whole, performance at higher levels in science knowledge and skills has improved significantly between 1996 and 1999.

• Many of the 1999 results do meet the expectations expressed by the pan-Canadian panel in science. In general, students did accomplish what is expected of them, in particular in the practical task assessment. In the written assessment, it was expected that slightly more students would be able to achieve at levels 4 and 5, demonstrating relatively sophisticated science knowledge and skills.

• 16-year-olds performed much better than 13-year olds. Although this will come as no surprise (same results in the 1996 study), this process makes it possible to measure and document with reliable statistics the achievement gap in science between those age groups across Canada. We can at least infer that our educational systems do foster the development of science knowledge and skills between the ages of 13 and 16.

• In the written assessment of science knowledge, more than three-quarters of 16-year-olds and more than half of 13-year-olds students reached level 3. In the practical assessment of science investigative skills, more than three-quarters of 16-year-olds and nearly half of 13-year-old students reached level 3.

4. IEA/TIMSS Study of Science Achievement, 1995, 1999, & 2003

In 1995, Canada along with 40 other countries participated in the Third International Mathematics and Science Study (TIMSS) for grades 3/4, 7/8 and 12 (or OAC in Ontario) students (TIMSS, 1995). The TIMSS project, a project of IEA was designed to compare the teaching/learning of math and science in elementary and secondary schools at an international level. The TIMSS project was repeated (TIMSS-R) in 1999, and involved 38 countries and the grade 8 students. The third study (results still unpublished) was done in 2003, and focussed on the grades 4 and 8 students.

Highlights of the science results from the 1995 and 1999 studies are taken from TIMSS-R Ontario Report (EQAO, 2000). The results were compared between years 1995 and 1999 as well as between Canada (national) ,Ontario, and internationally. Some of the findings are summarized below:

• In science the overall achievement of Ontario grade 8 students statistically improved between 1995 (TIMSS) and 1999 (TIMSS-R)

• In 1999, Canadian grade 8 students performed relatively well in science with 5 countries achieving results higher than Canada.

• In 1999, Ontario grade 8 students scored at the national average, and were significantly higher than the international average in all of the content areas - an obvious improvement in grade 8 students in Ontario.

• In 1999, boys outperformed girls both in Ontario and in Canada. In 1995, there were no measured gender differences.

• In 1995, Ontario grade 8 students scored at the same level as international students but below the national average, while Alberta and British Columbia students scored above it. (p. 11,12)

Chin, Munby and Krugly-Smolska (1997) believe that the differences between Ontario, Alberta and British Columbia can be explained on examining the structures of these three provincial school systems. Elementary school science is taught by generalist teachers, while secondary schools are staffed with subject-specialist teachers. In Alberta, British Columbia and Ontario, elementary school ends in grades 6, 7, and 8, respectively, with students in these provinces receiving 2, 1, and 0 years, respectively, of science instruction from a subject specialist. Thus, one important issue raised by Chin et al. was:"How will the scope and sequence of the new secondary science curriculum take into account the present structure of most Ontario school systems where K - 8 are taught by generalist teachers?" (p. 7)

These studies provided a continuing stimulus for the development of new science curriculum in Canada and Ontario.

2.1.C The Common Framework of Science Learning Outcomes, K-12

After examining data from research on the science curriculum provincially, nationally and internationally, curriculum developers developed the *Common Framework of Science Learning Outcomes, K - 12: Pan-Canadian Protocol for Collaboration on School Curriculum* which was released by the Council of Ministers of Education, Canada (1997). This Common Framework is a guideline to be used by curriculum developers which gives what outcomes should be achieved at each grade level in the overall science curriculum in all provinces in Canada.

The Assessment of Science and Technology Achievement Project (ASAP) coordinated by the Science Education Group at York University in Toronto developed the new curriculum document, *The Ontario Curriculum Grades 1-8: Science and Technology* (Ministry of Education and Training, 1998b). Originally, the outcomes developed by this team were intended for use by the 17 participating school boards although the Ministry of Education and Training did express the wish that it be disseminated province-wide (Chin et al., 1997). The knowledge and skills goals outlined in the curriculum document are based largely on those set forth in the *Common Framework of Science Learning Outcomes, K - 12: Pan-Canadian Protocol for Collaboration on School Curriculum* (Council of Ministers of Education, Canada, 1997).

The four foundation statements for scientific literacy in Canada from which the learning outcomes evolved are as follows:

Foundation 1: Science, technology, society, and the environment

Students will develop an understanding of the nature of science and technology, of the relationships between science and technology, and of the social and environmental contexts of science and technology.

Foundation 2: Skills

Students will develop the skills required for scientific and technological inquiry, for solving problems, for communicating scientific ideas and results, for working collaboratively, and for making informed decisions.

Foundation 3: Knowledge

Students will construct knowledge and understandings of concepts in life science, physical science, and Earth and space science, and apply these understandings to interpret, integrate, and extend their knowledge.

Foundation 4: Attitudes

Students will be encouraged to develop attitudes that support the responsible acquisition and application of scientific and technological knowledge to the mutual benefit of self, society, and the environment. (Council of Ministers of Education, Canada, 1997, section 4, p. 6)

This Common Framework can be seen as an attempt to develop a broad and comprehensive vision of science education in Canada from K - 12 (Chin et al., 1997) in order to define what science knowledge, skills, and attitudes students should possess when they leave secondary school so they are scientific literate and prepared for the 21st century, regardless of whether their destination is work, college, university or other post-secondary education. The Pan-Canadian Protocol (Council of Ministers of Education, Canada, 1997) has established within its framework the goals of Canadian science education which are:

- encourage students at all grade levels to develop a critical sense of wonder and curiosity about scientific and technological endeavours
- enable students to use science and technology to acquire new knowledge and solve problems, so that they may improve the quality of their own lives and the lives of others
- prepare students to critically address science-related societal, economic, ethical, and environmental issues
- provide students with a foundation in science that creates opportunities for them to pursue progressively higher levels of study, prepares them for science-related

occupations, and engages them in science-related hobbies appropriate to their interests and abilities

• Develop in students of varying aptitudes and interests a knowledge of the wide variety of careers related to science, technology, and the environment. (section 3, p. 5)

What should be taught in science cannot be isolated from how science should be taught. Chin et al. (1997) states that "if we want our future citizens of the 21st century to have a clear understanding of how science works, our curriculum should reflect the position that students need to experience how science works rather than just being told how science works. In this way, the subject matter becomes a means for achieving a broader aspect of scientific literacy rather than being the end in itself." (p. 7).

2.1.D The Teaching and Learning of Science

Connelly (1987) believes that science teaching has several inherent deficiencies. Connelly explains this by stating that in secondary schools specifically, the curriculum to be covered is so extensive that there is little time available for flexibility in teaching and also one of the main needs in science is for students to learn to deal with problems in a hands on, 'scientific' fashion. Time constraints, however, result in labs that simply confirm readily predictable outcomes and require no concept of the scientific method. At the elementary school level one of the main needs to be addressed is that over 80% of primary/junior teachers in Canada have no post-high school science courses and few of those that do have post-high school courses have studied science recently (Connelly). In order to find solutions to these problems in the teaching of science, one must look at the learning process and the impact that this has on teaching.

Many new theories of learning and their implications for teaching are entering the main stream of science education (Chin et al., 1997). Such concepts as constructivism are slowly becoming better known. Methods of instruction such as the P.O.E. (Predict-Observe-Explain) attempt to place more emphasis on the formation of concepts in science in the learner during the teaching of science. Extensive work has been done in Australia on development of teaching strategies consistent with the constructivist view. Gunstone (1995) links metacognition to conceptual change and constructivism:

> ...learners are appropriately metacognative if they consciously undertake an informed and self-directed approach to recognizing, evaluating and deciding whether to reconstruct their existing ideas and beliefs. By informed, I mean recognize and evaluate, with an understanding of learning goals, of relevant uses of the knowledge/skills/strategies/structures to be learned, of the purposes of particular cognitive strategies appropriate to achieving these goals, and of the process of learning itself. Hence I argue that metacognition and conceptual change are totally intertwined. (p. 133)

Another strategy to assist in the learning of science used in Canada has been to emphasize the linkage of science to social, environmental and technological issues.

Chin et al. (1997) summarize the issues surrounding how science should be taught in three important questions:

> • How should the science curriculum reflect what should be taught in conjunction with a clear view about the nature of learning and its implications for teaching?
>
> • How can the science curriculum be designed to encourage interpretation and understanding rather than transmission and recitation?
>
> • What emphasis should be placed on exposing students to authentic science activities?" (p. 11)

The teaching emphasis of the new curriculum is perhaps best summarized in *The Ontario Curriculum Grades 1 - 8: Science and Technology* (Ministry of Education and Training, 1998b) by the following general statement: These goals "can be achieved simultaneously through learning activities that combine the acquisition of knowledge with both inquiry and design processes in a concrete, practical context." (p. 4) The teaching of science through inquiry is not new. In the 1960's there were many inquiry based programs introduced and there have been many studies reported in the literature on their successes and failings (Haury, 1993). The expectations of the current Science and Technology (1998) document stresses the importance of the process skills of discovery learning. What is of particular relevance for this study is that the literature does give evidence that inquiry oriented teaching is "effective in fostering scientific literacy and understanding of science processes, . . . , critical thinking, . . . , positive attitudes toward science" (Haury, 1993, p. 2) among other things. It is also of particular note that Haury goes on to state that "It seems particularly important that inquiry-oriented teaching may be especially valuable for many under-served and under-represented populations" (p. 2). Hodson (1996) also supports the inquiry approach through laboratory work as he believes that labs need to be more meaningful and authentic to aid in the development of the student's knowledge base.

2.1.E The Inquiry Approach to Teaching and Learning of Science

One of the goals of science education in Ontario is to "develop the skills, strategies, and habits of mind required for scientific inquiry and technological design" *(The Ontario Curriculum Grades 1 - 8: Science and Technology,* Ministry of Education and Training, 1998b, p. 4). It should be noted that the inquiry approach to the teaching and learning of science in the *The Ontario Curriculum Grades 1 - 8: Science and Technology* (Ministry of Education and Training) bases its foundation on the inquiry approach to the teaching and learning of science in the National Science Education Standards (National Research Council, 1996). The National Science Education Standards (National Research Council) is an American standard for science education and outlines in detail what all students (including Canadian students) need to know, understand, and be able to do to become scientifically literate, and includes in its discussion the inquiry approach to the teaching and learning of science. Its vision includes excellence and equity. The Standards envisions that science is an "active process", and that the learning of science involves "hands-on" activities, and "minds-on" experiences. Inquiry is an intrinsic part of science teaching and learning, but is not the only approach to teaching science.

The National Science Education Standards (National Research Council, 1996) defines scientific inquiry as follows: "Scientific inquiry refers to the diverse ways in which scientists study their natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world" (p. 23). The general definition of inquiry in education (National Research Council) is stated as follows: "Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyse, and interpret data; proposing answers, explanations and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations" (p. 23). Inquiry in the Standards document is treated as both a learning goal and a teaching method.

The general standards for inquiry (Table 1) include both the abilities and understandings of inquiry, and are the same for all grades. The details of the fundamental abilities necessary to do scientific inquiry (Table 2) and the details of the fundamental understandings about scientific inquiry (Table 3) increase in complexity from K-12.

Table 4 gives a comprehensive listing of the science teaching standards, which apply to many teaching strategies, including inquiry which is a central part of the teaching standards. The inquiry component is clearly seen where the standards state that teachers of science at any grade level should be able to plan an inquiry-based science program, focus and support inquiries, and encourage and model the skills of scientific inquiry. (National Research Council, 1996a). These standards for science teaching are grounded in five assumptions (National Research Council, Science teaching standards section, ¶ 1):

- The vision of science education described by the Standards requires changes throughout the entire system.
- What students learn is significantly influenced by how they are taught.
- The actions of teachers are deeply influenced by their perceptions of science as an enterprise and as a subject to be taught and learned.
- Student understanding is actively constructed through individual and social processes.
- Actions of teachers are deeply influenced by their understanding of and relationships with students.

Because of the general nature of the teaching standards in Table 4, the National Science Education Standards (National Research Council, 1996) proposed the more specific and helpful essential features of classroom inquiry (Table 5) with the learner as the focus. These five essential features help students to "develop a clearer and deeper knowledge of some particular science concepts and processes" National Science Education Standards (National Research Council, 2000, p. 27) . Inquiries are sometimes labelled as either "full" or "partial", and refer to the proportion of a sequence of inquiry based learning experiences. Table 6 describes variations in the amount of structure, guidance, and coaching the teacher provides students for each of the five essential features of classroom inquiry as noted in Table 5. Inquiries can also be labelled as "open", left-hand column in Table 6 or "guided", right-hand column, and refers to the degree of structure and direction provided by the teacher.

Teachers provide coherent inquiry-based instruction through the use of instructional

Table 1

Content Standard for Science as Inquiry

Note. From National Science Education Standards: Inquiry and the National Science Education Standards, A Guide for Teaching and Learning, by the National Research Council, 2000, p. 18, Washington, D.C.: National Academy Press. Copyright 2000 by the National Academy Press

As a result of activities in grades K-12, all students should develop

- abilities necessary to do scientific inquiry.
- understandings about scientific inquiry.

Table 2

Content Standard for Science as Inquiry: Fundamental Abilities Necessary to Do Scientific Inquiry

Note. From National Science Education Standards: Inquiry and the National Science Education Standards, A Guide for Teaching and Learning, by the National Research Council, 2000, p. 19 Washington, D.C.: National Academy Press. Copyright 2000 by the National Academy Press

Grades K-4

- Ask a question about objects, organisms, and events in the environment.
- Plan and conduct a simple investigation.
- Employ simple equipment and tools to gather data and extend the senses.
- Use data to construct a reasonable explanation.
- Communicate investigations and explanations.

Grades 5-8

- Identify questions that can be answered through scientific investigations.
- Design and conduct a scientific investigation.
- Use appropriate tools and techniques to gather, analyze, and interpret data.
- Develop descriptions, explanations, predictions, and models using evidence.
- Think critically and logically to make the relationships between evidence and explanations.
- Recognize and analyze alternative explanations and predictions.
- Communicate scientific procedures and explanations.
- Use mathematics in all aspects of scientific inquiry.

Grades 9-12

- Identify questions and concepts that guide scientific investigations.
- Design and conduct scientific investigations.
- Use technology and mathematics to improve investigations and communications.
- Formulate and revise scientific explanations and models using logic and evidence.
- Recognize and analyze alternative explanations and models.
- Communicate and defend a scientific argument.

Table 3

Content Standard for Science as Inquiry: Fundamental Understandings About Scientific Inquiry

Note. From National Science Education Standards: Inquiry and the National Science Education Standards, A Guide for Teaching and Learning, by the National Research Council, 2000, p. 20 Washington, D.C.: National Academy Press. Copyright 2000 by the National Academy Press

Grades K-4

- Scientific investigations involve asking and answering a question and comparing the answer with what scientists already know about the world.
- Scientists use different kinds of investigations depending on the questions they are trying to answer.
- Simple instruments, such as magnifiers, thermometers, and rulers, provide more information than scientists obtain using only their senses.
- Scientists develop explanations using observations (evidence) and what they already know about the world (scientific knowledge).
- Scientists make the results of their investigations public; they describe the investigations in ways that enable others to repeat the investigations.
- Scientists review and ask questions about the results of other scientists' work.

Grades 5-8

- Different kinds of questions suggest different kinds of scientific investigations.
- Current scientific knowledge and understanding guide scientific investigations.
- Mathematics is important in all aspects of scientific inquiry.
- Technology used to gather data enhances accuracy and allows scientists to analyze and quantify results of investigations.
- Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories.
- Science advances through legitimate skepticism.
- Scientific investigations sometimes result in new ideas and phenomena for study, generate new methods or procedures for an investigation, or develop new technologies to improve the collection of data.

Grades 9-12

- Scientists usually inquire about how physical, living, or designed systems function.
- Scientists conduct investigations for a wide variety of reasons.
- Scientists rely on technology to enhance the gathering and manipulation of data.
- Mathematics is essential in scientific inquiry.
- Scientific explanations must adhere to criteria such as: a proposed explanation must be logically consistent; it must abide by the rules of evidence; it must be open to questions and possible modification; and it must be based on historical and current scientific knowledge.
- Results of scientific inquiry — new knowledge and methods — emerge from different types of investigations and public communication among scientists.

Table 4

Science Teaching Standards

Note. From National Science Education Standards: Inquiry and the National Science Education Standards, A Guide for Teaching and Learning, by the National Research Council, 2000, p. 22 Washington, D.C.: National Academy Press. Copyright 2000 by the National Academy Press

TEACHING STANDARD A:

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

- Develop a framework of yearlong and short-term goals for students.
- Select science content and adapt and design curricula to meet the interests, knowledge, understanding, abilities, and experiences of students.
- Select teaching and assessment strategies that support the development of student understanding and nurture a community of science learners.
- Work together as colleagues within and across disciplines and grade levels.

TEACHING STANDARD B:

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

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

TEACHING STANDARD C:

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

- Use multiple methods and systematically gather data about student understanding and ability.
- Analyze assessment data to guide teaching.
- Guide students in self-assessment.
- Use student data, observations of teaching, and interactions with colleagues to reflect on and improve teaching practice.
- Use student data, observations of teaching, and interactions with colleagues to report student achievement and opportunities to learn to students, teachers, parents, policymakers, and the general public.

Table 4 (continued)

Science Teaching Standards

Note. From National Science Education Standards: Inquiry and the National Science Education Standards, A Guide for Teaching and Learning, by the National Research Council, 2000, p. 23 Washington, D.C.: National Academy Press. Copyright 2000 by the National Academy Press

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

- Structure the time available so that students are able to engage in extended investigations.
- Create a setting for student work that is flexible and supportive of science inquiry.
- Ensure a safe working environment.
- Make the available science tools, materials, media, and technological resources accessible to students.
- Identify and use resources outside the school.
- Engage students in designing the learning environment.

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

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

TEACHING STANDARD F:
Teachers of science actively participate in the ongoing planning and development of the school science program. In doing this, teachers

- Plan and develop the school science program.
- Participate in decisions concerning the allocation of time and other resources to the science program.
- Participate fully in planning and implementing professional growth and development strategies for themselves and their colleagues.

Table 5

Essential Features of Classroom Inquiry

Note. From National Science Education Standards: Inquiry and the National Science Education Standards, A Guide for Teaching and Learning, by the National Research Council, 2000, p. 25 Washington, D.C.: National Academy Press. Copyright 2000 by the National Academy Press

- Learners are engaged by scientifically oriented questions.
- Learners give priority to **evidence**, which allows them to develop and evaluate explanations that address scientifically oriented questions.
- Learners formulate **explanations** from evidence to address scientifically oriented questions.
- Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.
- Learners communicate and justify their proposed explanations.

Table 6

Essential Features of Classroom Inquiry and Their Variations

Note. From National Science Education Standards: Inquiry and the National Science Education Standards, A Guide for Teaching and Learning, by the National Research Council, 2000, p. 29 Washington, D.C.: National Academy Press. Copyright 2000 by the National Academy Press

Essential Feature	Variations			
1. Learner engages in scientifically oriented questions	Learner poses a question	Learner selects among questions, poses new questions	Learner sharpens or clarifies question provided by teacher, materials, or other source	Learner engages in question provided by teacher, materials, or other source
2. Learner gives priority to **evidence** in responding to questions	Learner determines what constitutes evidence and collects it	Learner directed to collect certain data	Learner given data and asked to analyze	Learner given data and told how to analyze
3. Learner formulates **explanations** from evidence	Learner formulates explanation after summarizing evidence	Learner guided in process of formulating explanations from evidence	Learner given possible ways to use evidence to formulate explanation	Learner provided with evidence
4. Learner connects explanations to scientific knowledge	Learner independently examines other resources and forms the links to explanations	Learner directed toward areas and sources of scientific knowledge	Learner given possible connections	
5. Learner communicates and justifies explanations	Learner forms reasonable and logical argument to communicate explanations	Learner coached in development of communication	Learner provided broad guidelines to sharpen communication	Learner given steps and procedures for communication

More ——— Amount of Learner Self-Direction ——— Less

Less ——— Amount of Direction from Teacher or Material ——— More

models. "An instructional model incorporates the features of inquiry into a sequence of experiences designed to challenge students' current conceptions and provide time and opportunities for reconstruction, or learning, to occur" (Bybee, 1997, as cited in National Research Council, 2000, p. 34). Table 7 shows the common components that are shared by instructional models. All science should not be taught through inquiry, as the effective teaching of science requires a variety of strategies.

Classroom Assessment and Inquiry

In an inquiry-based classroom, assessment asks "what each student knows and understands, what is fuzzy or missing, and what students can do with what they know. Assessment determines whether students can generate or clarify questions, develop possible explanations, design and conduct investigations, and use data as evidence to support or reject their own explanations" (National Research Council, 2000, p. 75). The National Science Education Standards (2000) state that assessment needs to determine whether students are achieving the three major learning outcomes of inquiry based science teaching:

- conceptual understandings in science
- abilities to perform scientific inquiry
- understandings about inquiry" (National Research Council, 2000, p. 75)

The assessment formats and procedures in Table 8, not only show the various formats used to assess student learning (multiple choice, true/false, matching, essays, investigations, research reports, projects, portfolios, journals, labs, and notebooks) but also the increasing challenges teachers face as one moves from the left to the right side of the table as the outcome of assessment goes from right/wrong to needing criteria to determine a grade or level which then introduces some degree of subjectivity. Effective assessment will therefore require standards that teachers agree on at the school or district level.

Table 7

Common Components Shared by Instructional Models

Note. From National Science Education Standards: Inquiry and the National Science Education Standards, A Guide for Teaching and Learning, by the National Research Council, 2000, p. 35 Washington, D.C.: National Academy Press. Copyright 2000 by the National Academy Press

- Phase 1: Students engage with a scientific question, event, or phenomenon. This connects with what they already know, creates dissonance with their own ideas, and/or motivates them to learn more.
- Phase 2: Students explore ideas though hands-on experiences, formulate and test hypotheses, solve problems, and create explanations for what they observe.
- Phase 3: Students analyze and interpret data, synthesize their ideas, build models, and clarify concepts and explanations with teachers and other sources of scientific knowledge.
- Phase 4: Students extend their new understanding and abilities and apply what they have learned to new situations.
- Phase 5: Students, with their teachers, review and assess what they have learned and how they have learned it.

Table 8

Assessment Formats and Procedures

Note. From National Science Education Standards: Inquiry and the National Science Education Standards, A Guide for Teaching and Learning, by the National Research Council, 2000, p. 82 Washington, D.C.: National Academy Press. Copyright 2000 by the National Academy Press

	On demand ⟶			Over time
Formats	multiple choice, true/false, matching	constructed response, essays	investigations, research reports, projects	portfolios, journals, lab notebooks
Amount of time	typically ~1 min 2-3 min with justifications	1-2 min short answers 5-15 min open-ended responses	days, weeks, or months	months or even years
Whose questions? (audience for the answer)	anonymous or the teacher's	anonymous or the teacher's	the teacher's or the student's	the teacher's or the student's
What kind of questions?	posed narrowly	posed narrowly	posed more openly	varies
Source of answer	anonymous or the teacher's	the student's	the student's	the student's
What kind of answers?	right/wrong	extent of correctness	standards or criteria for quality	standards or criteria for quality
Resources available during assessment	usually none	none or some equipment	equipment, references	equipment, references
Opportunity for feedback, revision	none	usually none	usually some from teachers and peers	usually some from teachers and peers

2.1.F Assessment and Evaluation

The data collected from various types of assessments/evaluation can not only be used to determine grades, guide student learning, and evaluate the effectiveness of the instruction but also to plan lessons, evaluate the curriculum and inform policy, and assist in the determination of where resources should be allocated. The issues raised by Chin et al. (1997) on assessment centre around three questions:

- *What is the appropriate balance in the assessment of knowledge, skills, and attitudes?*
- *What should be the range of instruments used in the classroom assessment and standardised provincial assessments in science?*
- *How can prior learning assessments be designed to address problem-solving and conceptualising abilities, in addition to science content?*" (p. 16)

Chin et al. (1997) examine what should be done in assessment. The National Science Education Standards (1996) judges the quality of assessment practices. The assessment standards provide criteria in five areas:

- The consistency of assessments with the decisions they are designed to inform.
- The assessment of both achievement and opportunity to learn science.
- The match between the technical quality of the data collected and the consequences of the actions taken on the basis of those data.
- The fairness of assessment practices.
- The soundness of inferences made from assessments about student achievement and opportunity to learn (National Research Council, 1996, Assessment standards section, ¶ 1)

Assessment issues need to be considered at the classroom level, as well as the provincial level where large-scale standardised assessments of students are conducted. Assessment is generally defined as the collection and interpretation of information, and the recommendations concerning the performance of individuals, groups, or instructional units or programs (Chin et al, 1997). The recommendations concerning performance in Chin et al. is equivalent to the National Science Education Standards' (1996) feedback mechanism of assessment. Assessments inform students on how well they are meeting the expectations and teachers on how well their students are learning, provide school districts, boards, and policy makers on the effectiveness of their programs and policies, and guides the professional development of teachers.

The expert panel on sciences for key directions in secondary curriculum development, Ministry of Education and Training (1997), made several recommendations for key directions in secondary curriculum development with respect to assessment. The panel recommended on-going assessment of student outcomes, multiple and varied methods of assessment including practical hands-on assessments, open-ended problems, performance assessments, journal writing, portfolios, interviews, essays, and multiple choice to name a few. The panel also discussed using authentic assessments whenever possible with a science, technology, society and the environment (STSE) focus. This expert panel recommended that "to be most effective, assessment must be used both to measure students' achievement and, as an accountability mechanism to assess whether the program provides students with appropriate opportunities to learn" (section 3.8a, ¶ 4). The National Science Education Standards (1996) also recommended a similar variety of assessments that are developmentally and contextually appropriate for the students.

In order for new programs to be effectively implemented it is essential that testing procedures consistent with the aims of science education be used. Large-scale assessment is particularly susceptible to becoming content oriented, which in turn can lead to a similar emphasis in teaching. A number of types of assessment are discussed below. These assessments may be used to guide student learning, evaluate instructional effectiveness, evaluate the curriculum, as well as determine grades.

Performance Assessment

Performance testing in science is an assessment of performance on tasks frequently involving laboratory experimentation, computer simulations, open-ended written exercises and visual diagrams. Such assessments are administered individually or in groups. "Although performance assessment is not without its difficulties, the evidence is that these tasks produce trustworthy information" (Chin et al., 1997, p. 15).

Attitude Assessment

The assessment of attitude is one of the most difficult assessments to do. All attitude assessment instruments have failed to meet reasonable standards for reliability and validity because of its subjectivity (Chin et al., 1997). The direction which science education is being lead by the Ministry of Education, "science for all", has implicit in it the development of new attitudes towards science. At this point it is difficult to perceive how achievement of this goal can be verified unless new, more effective means of attitude assessment are developed.

New Thinking in Assessment

An expanded view of assessment is being developed aimed at developing a more authentic assessment procedure (Chin et al., 1997). First, the assessment tasks must be worth doing for their own sake, the assessment is an integral part of the learning experience, and the student develops new concepts and ideas in the process. "Second the assessment tasks are designed so that they resemble as closely as possible tasks encountered in settings beyond the classroom" (p. 15). An appropriate method of authentic assessment will also tend to direct the teaching process toward the goals of the Ministry. It is worth noting that the report of the Royal Commission on Learning (1994) recommended authentic assessment as an alternative to the usual tests which test primarily factual knowledge.

Provincial Testing

Standardized testing has potentially both positive and negative effects. "The emphasis on external standards, the competition that characteristically follows, the narrow focus on easily tested products of schooling are notably not the conditions that lead to the development of engaged, thoughtful, creative and continual learners." (Chin et al., 1997, p. 15) "A standardised achievement test is one that is given and scored in the same way whenever and wherever it is used so that the scores of all students can be compared. Standardized assessment may take many forms, including multiple choice questions, essays, and laboratory performance tests" (p. 15). Authentic assessment may be used in provincial assessments to obtain information about achievement and learning but so far this as not yet been done in science but in other areas e.g. in math and languages.

Inclusion and Assessment

The inclusive classroom poses special challenges to traditional assessment practices because the latter has typically depended on written responses to written test items. Without question, such instruments test reading and writing ability as well as the science they are intended to assess. Within the inclusive classroom teachers can expect to

> encounter students who have difficulty reading and writing, but those challenges should not prevent them from demonstrating their science learning" (Chin et al., 1997, p. 16).
>
> The document *Principles for Fair Assessment Practices for Education in Canada* reflects the Canada-wide concern about assessment practices. These principles were devised by a group advised by representatives from many professional groups - Canadian Education Association, Canadian School Boards Association, Canadian Teachers' Federation, Canadian Council For Exceptional Children to name a few" (Chin et al., 1997, p. 16).

In Ontario, the Education Quality and Accountability Office is responsible for assessment. It's mandate includes conducting provincial assessments of reading, writing, and mathematics in Grades 3, 6, 9, and 11.

2.1.G *The Ontario Curriculum Grades 1-8: Science and Technology*

(Ministry of Education and Training, 1998b)

2.1.G.i A Brief Summary

This section briefly summarizes the major components of the The Ontario Curriculum Grades 1-8: Science and Technology document (Ministry of Education and Training, 1998b) of which the method of scientific inquiry and design and assessment/evaluation tools are two components of the document.

The Goals of Science and Technology Education.

Before students enter secondary school, they need to develop "a basic scientific literacy and technological capability" through a combination of understanding the basic concepts of science and technology, learning and developing the skills of inquiry and design, developing communicating skills, and relating science and technology to each other, the society and the environment in which they live (Ministry of Education and Training, 1998b). The goals for student learning identified in this document are:

- to understand the basic concepts of science and technology;
- to develop the skills, strategies, and habits of mind required for scientific inquiry and technological design; and
- to relate scientific and technological knowledge to each other and to the world outside the school (p. 4).

Strands in the Science and Technology Curriculum.

The five strands of the Curriculum are:

1. Life Systems
2. Matter and Materials
3. Energy and Control
4. Structures and Mechanisms
5. Earth and Space Systems

The Role of Teachers.

Teachers are expected to facilitate the learning through the inquiry and design process with the use of more hands-on activities with concrete materials. This will allow the students to recognize, uncover, and distinguish essential and integral concepts by constantly experimenting, and this will also allow the students to situate the concept in a socially, environmentally, and economically relevant context. The teacher's job is therefore to "motivate students to learn in a meaningful way and to learn for life" (Ministry of Education and Training, 1998b, p. 6).

Scientific Inquiry and Technological Design.

In the inquiry process, students strive to understand the linkages and connections in their knowledge and understanding, while a student solves a practical problem through technological design. The central elements of inquiry and design are the following: "understanding the problem, making a plan, carrying out the plan, and looking back" (Ministry of Education and Training, 1998a, p. 40). The similarities and differences between the processes of scientific inquiry and technological design are illustrated in Table 9 (Ontario English Catholic Teachers Association [OECTA], 1998, p. 5).

The Assessment of Science and Technology Achievement Project (ASAP), completed by York University's Faculty of Education,17 school boards and over 300 teachers, developed standards and the framework for science and technology in 1995. This assessment was circulated and deliberated province-wide. The framework that exists today in the science and technology curriculum document is essentially the same as ASAP's framework (Bloch & Orpwood, 1996). ASAP's model for science and technology shown in Figure 1 (reprinted from Bloch & Orpwood, 1996, p. 1), demonstrates the inquiry/design and the Science-Technology-Society (STS) contexts as well as the arrangement of the science and technology content within these contexts. The

Table 9

Similarities and Differences Between Scientific Inquiry and Technological Design

Note. From *OECTA Teacher Resources: The Ontario Curriculum, Grades 1-8: Science and Technology* (p. 5), by the Ontario English Catholic Teachers Association,1998, Toronto: OECTA.

Common Problem-solving Processes	Science	Technology
Understanding the problem ▪ explore and state the problem ▪ analyse the components ▪ refine the statement	▪ seeks to describe and explain the natural and physical world ▪ seeks to answer the question "why"	▪ seeks to address real life problems and needs ▪ seeks to answer the question "how"
Making a plan ▪ explore range of possible materials and procedures ▪ choose the appropriate materials, procedures and techniques	▪ design investigations and experiments ▪ plan materials and method	▪ design devices, products or systems ▪ plan resources and procedures
Carrying Out the Plan ▪ monitor and adjust the plan ▪ document the process	▪ carry out investigations ▪ document observations	▪ build and test designs ▪ test product or system and document its performance
Looking Back ▪ assess results ▪ consider the implications and extensions	▪ does the experiment confirm the prediction? ▪ possible further investigations ▪ implications	▪ does the designed solution work? ▪ possible improvements in the device, product or system

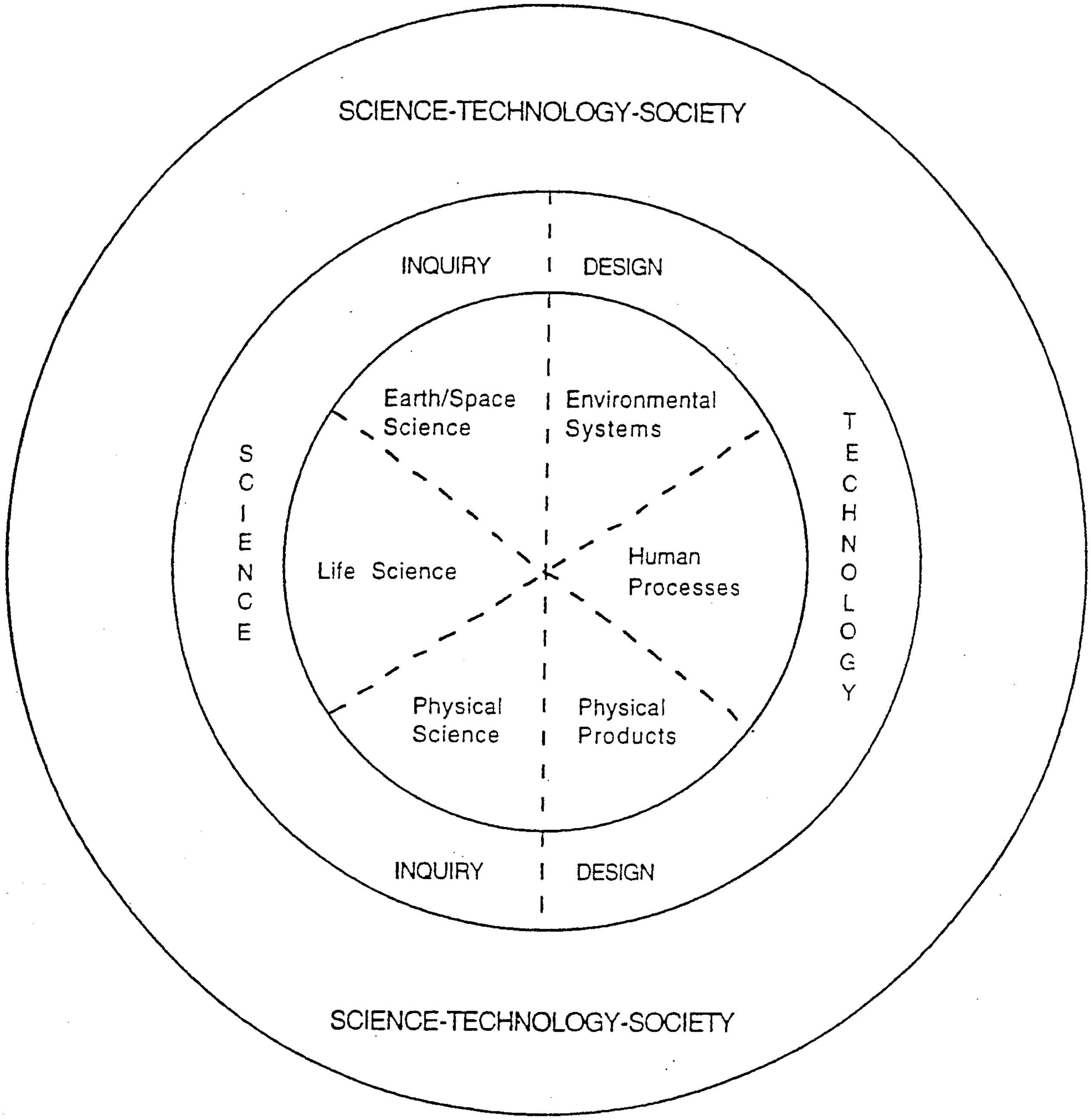

Figure 1. The ASAP model for science and technology.

Note. From *Assessment of Science & Technology Achievement Project: Working Paper #4, Ontario Curriculum Framework: Science and Technology, Grades 1-9: A Consultative Draft,* (p. 1), by M. Bloch and G. Orpwood, 1996, Toronto: York University. Copyright 1996 by York University.

dotted lines in the model indicate that content areas between STS and inquiry/design can be integrated. It was noted that the only difference between the current strands and ASAP's strands was that ASAP had the additional strand of Human Systems. The strands are not indicated on the diagram but each strand consists of specific content areas (for example: Earth and Space Systems consists of Earth Science and Environmental Systems). ASAP also developed achievement levels (1 - 4) to determine whether certain skills and strategies for inquiry and design were being met (Table 10) (reprinted from Ministry of Education and Training, 1998a, p. 86).

Skills that are important in inquiry and design are: communicating skills (talking, recording, reporting), mathematical skills (measuring/recording data, charting, graphing), and exploration skills (students actively question, students taught to ask better questions, all questions are important) (Ministry of Education and Training, 1998a).

Teacher Questioning.

Implementation Planner: *The Ontario Curriculum, Grades 1-8: Science and Technology* (Ministry of Education and Training, 1998a) stresses the importance of proper teacher questioning style to guide students through the inquiry process of solving the problem. Teachers need to ask students the most relevant question at the appropriate time based on what stage of the problem solving process the student is at. The teacher needs to guide the student to: "recognize the problem", "make the problem situation more specific", "establish possible solutions (during this step known data is extended)", "rate the alternatives",and "establish criteria for evaluation" (p. 39). Appropriate questions that the teacher might ask at each of these stages of inquiry are in Table 11 (reprinted from Ministry of Education and Training, 1998a, p. 39).

Assessment.

Teachers will assess and evaluate the students using a number of tools. One of the tools is the use of achievement levels (1 - 4) shown in Table 12 (reprinted from Ministry of Education and Training, 1998b, p. 13). In addition to communication skills, the students' level of achievement in "understanding the basic concepts of science and technology, developing the skills and strategies required for scientific inquiry and technological design, including the

Table 10

Assessment for Science and Technology Achievement Project

Note. From *Implementation Planner: The Ontario Curriculum, Grades 1-8: Science and Technology* (p. 86), by the Ministry of Education and Training, 1998a, Toronto: Queen's Printer for Ontario. Copyright 1996 by York University.

Criteria	Level 1	Level 2	Level 3	Level 4
MET indicator	- applies few of the required skills and strategies	- applies some of the required skills and strategies;	- applies most of the required skills and strategies	- applies all of the required skills and strategies
Initiating and Planning Understanding the need	- does not demonstrate an understanding of the task;	- demonstrates a partial understanding of the task;	- demonstrates a basic understanding of the task;	- demonstrates a thorough understanding of the task
Making a plan	- no set of procedures or plan for designing a product is attempted, or the procedures or plan are incoherent or unworkable;	- develops a set of procedures and/or plan for designing a product that is limited in appropriateness, efficiency, clarity, and/or completeness;	- develops a set of procedures and/or plan for designing a product that is appropriate but is limited in efficiency, clarity, or completeness	- develops a set of procedures and/or plan for designing a product that is appropriate, efficient, clear, and complete;
	- does not identify or control variables, or take into account predetermined criteria;	- identifies and controls some variables, and takes into account some predetermined criteria;	- identifies and controls most major variables, and takes into account most predetermined criteria;	- identifies and controls major variables, and takes into account all predetermined criteria;
Performing and Recording Carrying out the plan	- does not follow any procedures or plan to conduct a fair test or develop a product;	- follows most identified procedures or parts of a plan to conduct a fair test or develop a product;	- follows identified procedures or a plan to conduct a fair test or develop a product, and makes some modifications;	- follows identified procedures or a plan to conduct a fair test or develop a product, and justifies modifications;
	- data is not recorded or is irrelevant to the problem;	- data is of limited relevance to the problem, is limited in scope, and/or contains major inaccuracies;	- data is relevant to the problem and sufficient in scope and detail, but not extensive;	- data is relevant to the problem and may be extensive in scope and detail;
	- display of information is disorganized, not precise, accurate or complete;	- display of information is somewhat organized, and somewhat precise, accurate and complete;	- display of information is organized and mostly precise, accurate and complete;	- display of information is organized, precise, accurate and complete;
	- units are not indicated;	- units are often incorrect or are not included;	- most units are included;	- all units are included;
Analysing and Interpreting	- relevant data and/or criteria are not analysed or explained;	- relevant data and/or criteria are partly identified and explained, without analysis;	- relevant data and/or criteria are identified and explained, but analysis is incomplete;	- relevant data and/or criteria are identified, analysed and explained;
Looking back	- conclusion/ inference is absent, incoherent, illogical or irrelevant, and not supported by the data or performance of the design;	- conclusion/ inference is not well supported by the data or performance of the design; or is partially supported by the data and performance and is not clearly stated;	- conclusion/ inference is valid, understandable and supported by the data or performance of the design;	- conclusion/ inference is valid, clearly stated and well supported by the data or performance of the design;
	- conclusion does not address the original task;	- conclusion partly addresses the original task;	- conclusion addresses the original task;	- conclusion fully addresses the original task;

Table 11

Teacher Questioning to Guide Inquiry

Note. From *Implementation Planner: The Ontario Curriculum, Grades 1-8: Science and Technology* (p. 39), by the Ministry of Education and Training, 1998a, Toronto: Queen's Printer for Ontario. Copyright 1998 by the Queen's Printer for Ontario.

• **Recognize the problem** through: - intuition - observation (using the five senses) • *Is there a willingness and/or a need to solve the problem?*	• What questions should you try to answer? • What seems to be going on? • What do you see? (senses) • Is there something wrong? • What is being asked? • How do you feel about this situation? • Is there a problem?
• **Make the problem situation more specific** through: - clarification - classification - application of known data • Verbalize or write the problem. • *Has the real problem been defined?*	• What do you want? • What do you want to know? • What do you want to achieve? • What is being asked? • What is the problem? • How can you make the problem simpler? (more manageable?)
• **Establish possible solutions** through: - idea production strategies (e.g., brain-storming, lateral thinking, image building, forecasting, hypothesizing) • Organize the information through - collection, classification and application data • *Are there any possible solutions for the problem as defined?*	• How is this problem similar to one that has been done before? • What could you do? • What resources can be used? • What ideas do you have? • Estimate (guess) how much (many, long, high, deep). • How can I help?
• **During this step, known data is extended** by using: - primary and secondary sources - subjective and objective data - experimentation - idea production - priority setting - trial and error • Establish criteria for a solution. • Apply criteria to each possible solution and predict consequences (forecasting). • Compare possible solutions. • *Should other possible solutions be considered?*	• What would happen if ...? (consequences) • What do you like about this solution? • Will this solution get you what you want? • What criteria should you use to evaluate your solutions? • Which criteria are most important? • How might this solution affect you? affect others? • Is there enough information? • What conclusions can be made? • Would a combination of alternatives be appropriate?
• **Rate the alternatives.** • Make a decision!	• What seem(s) to be the most appropriate choice(s)?
• **Establish a plan for action.** • Do it!	• What will you do? • What steps will you take? • What resources will you need? • What is your timeline? • What problems might you encounter?
• **Establish criteria for evaluation.** • Assess the end result and the process. • *Has the problem been solved satisfactorily? Why/why not?*	• How will you know if your solution is/is not working? • Did it work: Why/why not? • What else should you have considered? • What did you learn?

Table 12

Science and Technology Achievement Levels

Note. From *The Ontario Curriculum, Grades 1-8: Science and Technology* (p. 13), by the Ministry of Education and Training, 1998b, Toronto: Queen's Printer for Ontario. Copyright 1998 by the Queen's Printer for Ontario.

Knowledge/Skills	Level 1	Level 2	Level 3	Level 4
Understanding of basic concepts	**The student:**			
	– shows understanding of few of the basic concepts	– shows understanding of some of the basic concepts	– shows understanding of most of the basic concepts	– shows understanding of all of the basic concepts
	– demonstrates significant misconceptions	– demonstrates minor misconceptions	– demonstrates no significant misconceptions	– demonstrates no misconceptions
	– gives explanations showing limited understanding of the concepts	– gives partial explanations	– usually gives complete or nearly complete explanations	– always gives complete explanations
Inquiry and design skills (including skills in the safe use of tools, equipment, and materials)*	**The student:**			
	– applies few of the required skills and strategies	– applies some of the required skills and strategies	– applies most of the required skills and strategies	– applies all (or almost all) of the required skills and strategies
	– shows little awareness of safety procedures	– shows some awareness of safety procedures	– usually shows awareness of safety procedures	– consistently shows awareness of safety procedures
	– uses tools, equipment, and materials correctly only with assistance	– uses tools, equipment, and materials correctly with some assistance	– uses tools, equipment, and materials correctly with only occasional assistance	– uses tools, equipment, and materials correctly with little or no assistance
Communication of required knowledge	**The student:**			
	– communicates with little clarity and precision	– communicates with some clarity and precision	– generally communicates with clarity and precision	– consistently communicates with clarity and precision
	– rarely uses appropriate science and technology terminology and units of measurement	– sometimes uses appropriate science and technology terminology and units of measurement	– usually uses appropriate science and technology terminology and units of measurement	– consistently uses appropriate science and technology terminology and units of measurement
Relating of science and technology to each other and to the world outside the school	**The student:**			
	– shows little understanding of connections between science and technology in familiar contexts	– shows some understanding of connections between science and technology in familiar contexts	– shows understanding of connections between science and technology in familiar contexts	– shows understanding of connections between science and technology in both familiar and unfamiliar contexts
	– shows little understanding of connections between science and technology *and the world outside the school*	– shows some understanding of connections between science and technology *and the world outside the school*	– shows understanding of connections between science and technology and the *world outside the school*	– shows understanding of connections between science and technology and the *world outside the school*, as well as their implications

* It should be noted that all students, regardless of their level of achievement, receive basic instruction in the safe use of tools, equipment, and materials.

techniques involved in the safe use of appropriate tools and equipment, and developing the ability to relate science and technology to each other and to the world outside the school" (p. 7) will be determined. Level 3 is the provincial standard, level 4 exceeds the standard, level 2 is below the standard. As an example, a level one student would show 'a few', a level 2 'some', a level 3 'most', and a level 4 'all' of the knowledge/skills being identified.

2.2 Curriculum Implementation

2.2.A General Concepts

2.2.A.i Introduction

Although this research does not attempt to assess the success of the implementation process at the provincial level, for analysis and discussion purposes it is necessary to have some concept of what constitutes successful implementation.

Fullan (1992) states that "Educational change fails many more times than it succeeds. One of the main reasons is that implementation - or the process of achieving something new into practice - has been neglected" (p. vii). Fullan goes on to say that there are two main reasons for focusing on implementation: first, "we do not know what has changed (if anything) unless we attempt to conceptualize and measure it directly" (p. 21) and second " we can begin to identify the reasons why innovations fail or succeed" (p. 22). This focus began in the early 1970's when it became apparent that many of the educational innovations of the 1950's and 1960's failed to meet their objectives (McLaughlin, 1976/1997). Change is "a process occurring over time, usually a period of several years" (Hord, Hall, Rutherford & Huling-Austin, 1987, p. 6) and according to Roberts and Roberts (1986) usually 3 to 5 years is required for the implementation of a major innovation.

In a review of research on the implementation process Fullan and Pomfret (1975) define implementation as the "actual use of the innovation" (p. 4). They go on to indicate that there are two basic concepts of the criteria to be used in evaluating implementation success. The first is defined as the "degree to which the innovation is implemented as planned" (p. 4) or in other words the "fidelity with developers' or sponsors' conceptions of the innovation" (p. 4). The second is "the degree to which the innovation is a product of a mutual adaptation between developers' and users' conceptions during the planning, adoption and especially the implementation process" (p. 5).

The first of these, fidelity of implementation, "treats teachers as passive recipients of the wisdom of the curriculum developers; teachers must be thoroughly trained to use the new curriculum, but, once trained, they will be able to teach it at a high level of technical proficiency"

(Marsh & Willis, 1999, p. 233). Harris (2003) also discusses the limited role teachers had in the New South Wales history syllabus (NSW) development where bureaucratic bodies were dictating not only what educational changes should occur but the how, when, and why, and yet these teachers were subjected to rigorous accountability mechanisms. Harris, and Hall (1997) found that teachers with negative views of their marginalised role were initially most probably non-committed, while teachers with positive views were committed to the change. In the extreme, this concept lead curriculum developers to try to design teacher-proof curriculum packages which evoked responses in teachers that resulted in implementation failure. Marsh and Willis summarize the results: "in districts and schools where teacher-proof curricula were adopted, often they were never implemented or implementation was quickly abandoned; and in the relatively few schools where they were implemented, teachers almost always found ways to modify them in practice to fit specific classroom realities, that developers have been unable to foresee" (p. 233). Harris found that individuals and groups manage the tensions and unequal power relations of "subject-specific curriculum change where issues of what constitutes subject knowledge, why and how it is best taught, learnt and assessed" (p. 54) are issues which creates conflicts or acceptance.

The second measure of successful implementation was popularized by the association of M. W. McLaughlin with the Rand Change-Agent Study in the early 1970's. This study concluded that "successful implementation is characterized by a process of mutual adaptation" (McLaughlin, 1976/1997, p. 168). This process of mutual adaptation can be characterized as a "dynamic organizational process that was shaped over time by interactions between the project goals and methods, and the institutional setting" (p. 168). Three levels of implementation were described:

> One, *mutual adaptation*, described successfully implemented projects. It involved modification of both project design and changes in the institutional setting and individual participants during the course of implementation.
>
> A second implementation process, *cooptation*, signified adaptation of the project design, but no change on the part of participants or the institutional setting. When implementation of this nature occurred, project strategies were simply modified to conform in a pro forma fashion to the traditional practices the innovation was expected to replace - either because of resistance to change or

> inadequate help for implementers.
>
> The third implementation process, *nonimplementation*, described the experience of projects that either broke down during the course of implementation or were simply ignored by project participants. (p. 168)

McLaughlin (1976/1997) identified "three specific strategies that are particularly critical" (p. 170) in successful implementation:

> *Load Material Development*
>
> In almost all of the classroom organization projects, the staff spent a substantial amount of time developing materials to use in the project classrooms .... providing the staff with an opportunity to "learn by doing" .... gave the staff a sense of "ownership" .... and provided a sense of "professionalism" and cooperation .... Although such "reinvention of the wheel" may not appear efficient in the short run, it appears to be a critical part of the individual learning and development necessary for significant change. (p. 170-171)
>
> *Staff Training*
>
> Some commentators on the outcomes of planned change contend that where innovations fail, particularly innovations in classroom organization, they fail because their planners overlooked the "resocialization" of teachers. Even willing teachers have to go through a *learning (and unlearning) process* in order to develop new attitudes, behaviours, and skills for a radically new role. Concrete, inquiry-based training activities scheduled regularly over the course of project implementation provide a means for this developmental process to occur. (p. 172)
>
> *Adaptive Planning and Staff Meetings*
>
> Past research on the implementation is almost unanimous in citing "unanticipated events" and "lack of feedback networks" as serious problems during project implementation. Routinized and frequent staff meetings combined

with on-going, iterative planning can serve to institutionalize an effective project feedback structure, as well as provide mechanisms that can deal with the unanticipated events that are certain to occur. (p. 172)

The debate about which of these two perspectives is the most appropriate in defining successful implementation of an innovation in education continues to this day. Marsh and Willis (1999) summarize current thinking in the statement "the real debate is not about fidelity versus adaptation but how to honour both fidelity and adaptation simultaneously" (p. 238).

2.2.A.ii The Overall Process

Marsh and Willis (1999) discuss four major processes of new curriculum implementation used in recent decades. These overall processes are Organizational Development, Action Research, Concerns-Based Adoption Model and Curriculum Alignment.

Organizational Development (OD) focuses on the group as a whole be it a school, a school board or a provincial education system and tries to develop a positive climate for change within the organization. The process by which this is done is related to behavioural science where the focus is on improving communication within the organizational system rather than on communication between individual members of the organization.

The Action Research process is a sequential process where a general plan of the innovation is decided on then implemented (an action step). The effects are then monitored, evaluated and a revised general plan developed leading to a second action step. The process continues as the implementation becomes more developed.

The Concerns-Based Adoption Model (CBAM) focuses on changes to the individual (feelings, attitudes, thoughts, or reactions and skills) and the interrelations between individuals (Hord, 1981; Loucks, 1983) and can be used to describe the stage in the teacher's feelings about the new innovation or to measure the teacher's growth if used on more than one occasion. Through these changes the system will be changed. Applying CBAM in the current context, those wishing change in the educational system would gather data about teachers' concerns in order to provide a resource system to facilitate change in the teachers until teachers are able to maintain the system on their own. This is evidenced in the support given to teachers after their specific concerns were determined in the Jeffco science program (Hall et al., 1980) and in the math program (Hord & Huling-Austin, 1987).

The concept of Curriculum Alignment is closest to the present implementation process. "Basically, curriculum alignment attempts to ensure maximum congruency between the planned curriculum and the enacted curriculum through extensive testing of what is taught" (Marsh & Willis, 1999, p. 254). The planned curriculum is generally developed by well trained specialists after an informed consensus has been obtained. The result is an official document, a curriculum framework, which all are required to follow. Marsh and Bowman (cited in Marsh & Willis) suggest that some factors assisted in the reported success of change through Curriculum Alignment in California. These included the following:

- The content of the reform was targeted at all students and constituted a toughening of existing academic programs.
- The local implementation process was stimulated by external pressure, especially in the form of testing.
- The content of the reform extended across the school and included alignment of curriculum, textbooks, teaching strategies, and testing.
- The roles of state, district and school were complimentary. (p. 255)

If we simply replace 'state' with 'province' and 'district' with 'board' in the above these circumstances are strikingly similar to those surrounding the present curriculum implementation process in Ontario.

2.2.A.iii Change Implementation

This section examines the major barriers to implementation and the major factors facilitating implementation.

Implementation in the Classroom

A new curriculum is only a plan for change. Until the plan is implemented by the teacher in the classroom 'real' change has not occurred. Hall, Wallace and Dossett (as cited in Marsh & Willis, 1999) developed a sequence of stages that teachers went through when introducing an innovation into the classroom based on the sequence of concerns found by Fuller (1969) for preservice teachers as they gained teaching experience. The Stages of Concern (SoC) sequence shown in Figure 2 (reprinted from Marsh & Willis, 1999, p. 246) has been "confirmed by a number of studies" (p. 245) and, although generally linked to CBAM, it provides valuable insights into the concerns of teachers during the introduction of an innovation into the classroom. From the broad perspective stages 0, 1 and 2 focus on concerns about oneself, stage 3 focuses on concerns about doing the task and stages 4, 5 and 6 concerns about the impact of the innovation on students and others. Hall and Loucks (1977) present a method of measuring the intensity of concern of an individual for each stage of concern in the model producing an individual concerns profile. These profiles can be useful in directing in-service activities of schools and school boards towards areas in which teachers show the most concern (Daniel & Stallion, 1995; Munger, 1991, 1995) and the assistance should be on-going and targeted to meet individual teacher's needs (Loucks-Horsley et al., 1987).

There are many reasons why teachers may resist change, several of which have been summarized by Ornstein and Hunkins (1993). Many reasons are relevant to this discussion on implementation. One is "lack of ownership" (p. 307). People resist change if the demand for change comes from outside. *The Ontario Curriculum Grades 1 - 8: Science and Technology* (Ministry of Education and Training, 1998b) has been introduced by the government at a time of tremendous stress between the government and teachers and, although there has been considerable input to the curriculum by various teachers and their organizations, the authoritarian style in which other aspects of education reform have been implemented may serve to alienate teachers and reduce their enthusiasm for curriculum reform. Eastwood and Louis (1992) and Stiegelbauer, Muscella and Rutherford (1986) discuss the involvement of staff in all stages of the implementation process so that they would feel that they had some input into it . Secondly, "lack of benefit" (Ornstein & Hunkins, p. 307) for student learning and teacher rewards may influence implementation. Such factors as the detailed nature of the curriculum framework may be seen by some teachers as restricting their ability to adapt to different student needs as well as restricting their ability to teach what they feel is important, thus taking the students education out of their hands. There can be little doubt that the changes will result, at least temporarily in an "increased burden" (p. 307) on most teachers since few elementary teachers are skilled in science so for most teachers implementation will require a lot of revision and review.

Harlen and Holroyd's (1995) two year study by the Scottish Council for Research on 514 primary teachers' understanding of concepts in science and technology found that many teachers

Stages of Concern		Definitions
0	Awareness	Little concern about or involvement with the innovation is indicated.
1	Informational	A general awareness of the innovation and interest in learning more detail about it are indicated. The person seems to be unworried about himself or herself in relation to the innovation. She or he is interested in substantive aspects of the innovation in a selfless manner, such as general characteristics, effects, and requirements for use.
2	Personal	Individual is uncertain about the demands of the innovation, his or her adequacy to meet those demands, and his or her role in the innovation. This includes analysis of his or her role in relation to the reward structure of the organization, decision making, and consideration of potential conflicts with existing structures or personal commitments. Financial or status implications of the program for self and colleagues may also be reflected.
3	Management	Attention is focused on the processes and tasks of using the innovation and the best use of information and resources. Issues related to efficiency, organizing, managing, scheduling, and time demands are utmost.
4	Consequence	Attention focuses on impact of the innovation on students within teacher's immediate sphere of influence. The focus is on relevance of the innovation for students, evaluation of student outcomes, including performance and competencies, and changes needed to increase student outcomes.
5	Collaboration	The focus is on coordination and cooperation with others regarding use of the innovation.
6	Refocusing	The focus is on exploration of more universal benefits from the innovation, including the possibility of major changes or replacement with a more powerful alternative. Individual has definite ideas about alternatives to the proposed or existing form of the innovation.

Figure 2. The stages of concern (SoC) sequence

Note: From *Curriculum: Alternative approaches, ongoing issues - second edition* (p. 246), by D.D. Marsh and G. Willis, 1999, Upper Saddle River, NJ: Prentice-Hall.
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felt that they were insufficiently trained to teach science and technology. Confident teachers were found to have some science qualifications or background, and those teachers that had done science beyond secondary school had a better understanding of science than teachers with no science background. However, there were some teachers with no science background, but yet understood the big science ideas. The data also showed that many teachers had a sound grasp of general knowledge which allowed them to teach science and technology with a fair degree of confidence, yet many of these teachers were uncertain that their understanding would be sufficient to assist their students in their conceptual development.

Other obstacles to implementation (Ornstein & Hunkins, 1993) may be related to "insecurity" (p. 307) and "chaos"(p. 308). The inquiry centred classroom is not as structured as has been the case in the classroom of the past and can be perceived as requiring a sounder grasp of science fundamentals. It seems likely that this will induce some teachers to feel that they will have less control over the learning process and question their own ability to ask the right question at the right time.

Hendrickson, O'Shea, Gable, Heitman and Sealander (1993) believe that a favourable means of implementing new programs with the final aim of improving classroom instruction is through effective in-service workshops, not the traditional quick but inadequate and ineffective in-service training sessions (Englert, Tarrant, & Rozendal, 1993).

Building Professional Learning Communities

Fullan and Stiegelbauer's (1991) key factors that affect the implementation of an innovation or change were grouped under three main categories: characteristics of the innovation, local roles, and external roles; the greater the number of factors facilitating implementation, the greater the change. The category, characteristics of the innovation, includes the following factors: need, clarity, complexity, quality and practicality. To facilitate change, users must regard the innovation as fulfilling a need as Casper and Roecks (1982) observed. If the change is simple and clear enough to be understood, the permanency of the change will be more likely. To facilitate change, users must regard the innovation as being practical or relevant and easy to understand (Shoyer 1990, p. 4). If the time factor is reasonable, and the materials needed are available, the change will be facilitated.

The category, local roles, include the local factors: the school, the board, the community, the principal and the teacher of which the principal change agents are the principal and the teacher (Fullan & Stiegelbauer, 1991). The more supportive the principal is of the implementation process, the more likely the change will occur (Fullan & Stiegelbauer, 1991). The more open to change teachers are individually as well as collectively in a collaborative environment the more likely change will be facilitated. Because of the critical role teachers play in the implementation process, it is very important that the challenges they experience be seriously addressed.

The category external roles, includes the factor of education policies and legislation. The facilitation of new policies and legislation can be favourably affected by support via resources, and professional development of staff, and by ongoing observation and constant adaptation to the change.

Proudford (2003) in her Queensland study of the restructuring of the 1-10 curriculum, discusses the building of professional learning communities for curriculum change. Teachers identified not only the major barriers to implementation (categorized under knowledge, organization, subjective/emotional realities, resources, and professional development), but the major factors that would facilitate implementation (categorized under vision, school organization, curriculum organization, professional development, and resources) the details of which are summarized in Tables 13 and 14, respectively. The principals at these schools, upon examining the challenges and solutions, felt that if the schools and educators worked together as a cluster in developing programs, the reculturing of schools would occur. This would create "professional learning communities to generate organizational learning and develop organizational capacity" with resulting change (Proudford, 2003, p. 2). Fullan (1993,1998a) and other writers (Hargreaves, 1997b; Kruse & Louis, 1995; Lieberman & Miller, 1999; McLaughlin & Talbert, 1993; Newmann & Wehlage, 1995) see the importance of reculturing schools to create professional learning communities. Newmann and Wehlage (p. 30) believe that a professional community is one where teachers share common goals concerning student learning, collaboratively work together to achieve that goal, and are as a group responsible for student learning. Figure 3, A Framework for Building Professional Learning Communities, shows the key component factors of this change process. The framework emphasizes that school cluster planning requires professional and emotional support and included in these supports there must exist curriculum leadership. Teachers from the Proudford (2003) study felt that this reculturing of the schools "provides opportunity to use time efficiently; share workloads, expertise and resources; and gain insights into how teachers in other settings interpret and adapt the syllabuses" (Proudford, p. 4).

Table 13

Major Barriers to Implementation

Note. From Proudford, C (2003). Building Professional Learning Communities for Curriculum Change. *Curriculum Perspectives, 23(3), September*

KNOWLEDGE
- open-ended nature of the syllabuses
- lack of understanding of outcomes-based concepts
- lack of understanding of implementation procedures

ORGANISATION
- lack of communication and collaboration
- staff and year level-changes

SUBJECTIVE/EMOTIONAL REALITIES
- feeling deskilled
- sustaining energy and motivation
- workload
- stress

RESOURCES
- insufficient resources, support materials
- time: to develop understanding and confidence; to plan; to allocate sufficient attention to all the KLAs

PROFESSIONAL DEVELOPMENT
- inequitable inservice

Table 14

Major Factors Facilitating Implementation

Note. From Proudford, C (2003). Building Professional Learning Communities for Curriculum Change. *Curriculum Perspectives, 23(3), September*

VISION
- clear, agreed expectations with total staff involvement

SCHOOL ORGANISATION
- opportunities to network before, during and after implementation
- success sharing
- communication

CURRICULUM ORGANISATION
- clear, user-friendly plans
- guidelines for assessment and reporting
- year-level discussions and planning

PROFESSIONAL DEVELOPMENT
- sound inservice, workshops in school time
- workshops to discuss concerns and misunderstandings, implement, go back to inservice to discuss problems
- professional assistance in class
- ongoing support

RESOURCES
- time for planning, trialling
- support materials

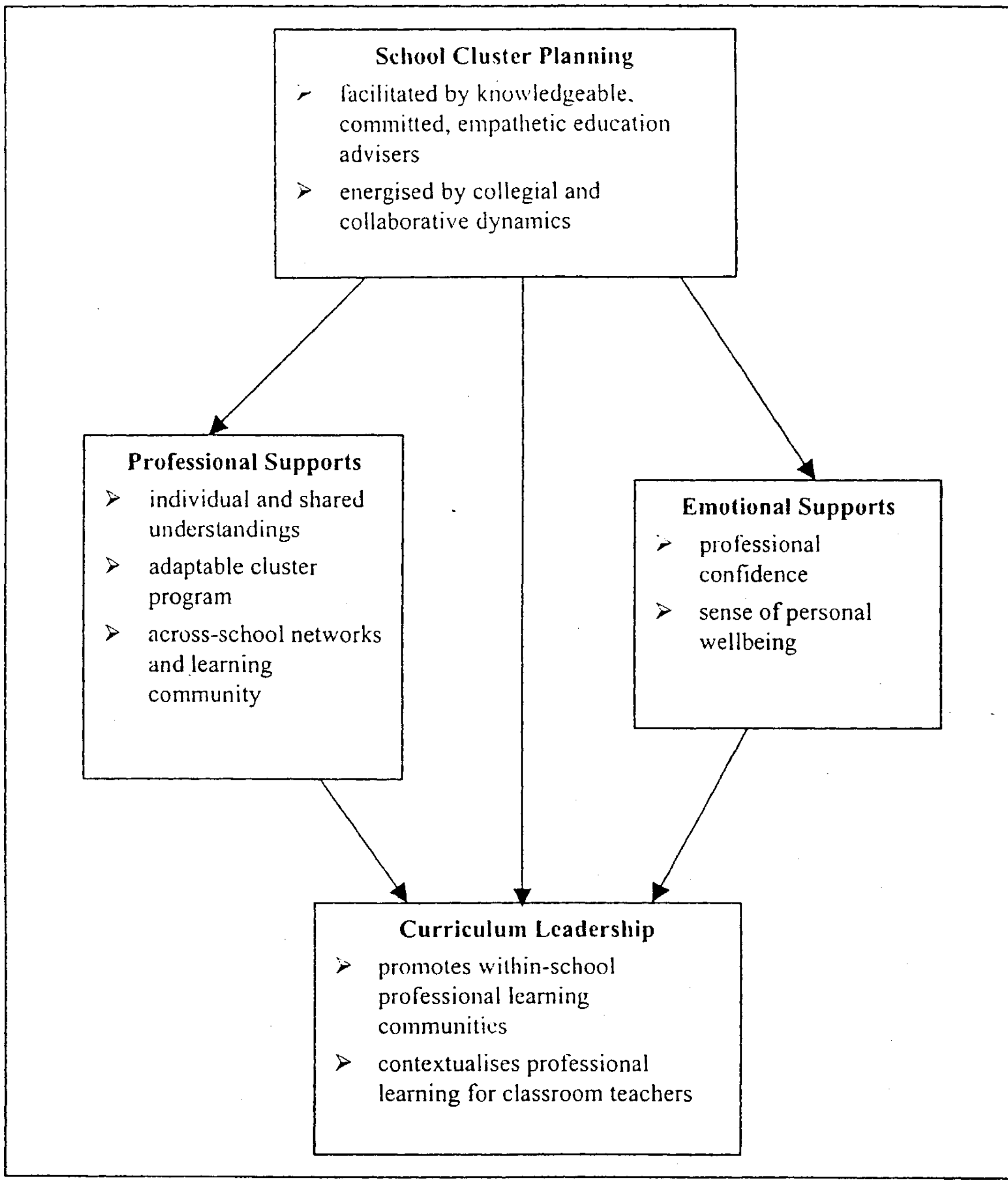

Figure 3.

A Framework for Building Professional Learning Communities

Note. From Proudford, C (2003). Building Professional Learning Communities for Curriculum Change. *Curriculum Perspectives, 23(3), September*

Professional Development and Other Forms of Help

Research (Cusworth & Dickson, 1994; Fullan, 1991; Hall & Hoard, 1987; Hargreaves, 1997a; Lovat & Smith, 1995) shows without doubt that for true, significant change in curriculum, professional development must be constantly ongoing, changing to meet the needs of the teachers and the school, and teacher driven. The traditional focus on workshops at the beginning of the implementation process is considered ineffective as change is a process that takes time (Englert et al., 1993; Wood & Thompson, 1993).

For change to occur, behaviours must be changed and teachers need help doing so (Hord et al., 1987). Teachers do this every time they get together with each other or with a facilitator to discuss a problem with the intent of finding a solution (Stiegelbauer et al., 1986). Thompson, Wood and Russell (1981) believe that a personal as well as a group commitment is required to facilitate change. Sparks and Loucks-Horsley (1989) believe that it is the companionship or peer coaching among individuals that will facilitate change.

Harlen and Holroyd's (1995) study found that the teachers wanted help in the following areas: "in-service courses, print-based resources, time to think and prepare, more and improved equipment, a school policy on what to teach and when, advice from specialists, and improvement in coordination and support within the school, pre-service science education courses. ...introducing and managing practical investigations, assessment and recording" (p. 10). Harlen and Holroyd found that despite the challenges that teachers faced, and despite the fact that they wanted help, most of the teachers in this study were happy with their teaching of science, which was not focussed on conceptual development in their students, but which made the most of the teaching skills that they possessed while avoiding areas where they were not confident.

2.2.B The Common Curriculum: The Change Experience

The change experience of the previous curriculum is examined to aide in the understandings of the effects, including the challenges and solutions, of large scale change as in the current curriculum. The Common Curriculum, Policies and Outcomes, Grades 1 to 9 (Ministry of Education and Training, 1995) is a Ministry of Education and Training policy document that states the demonstrable, measurable, learning outcomes that students should attain by the end of grades 3, 6 and 9 through a constructivist approach to learning and integration in the four program areas of the Arts, Language, Mathematics, Science and Technology, and Personal and Social Studies.

The Common Curriculum precipitated systemic reform across the province (Vinovskis, 1996) resulting in the current curriculum today. Vinovskis, who questions whether systemic reform creates more effective schools, provides this definition of systemic reform "Expanding the role of the states in public education, emphasising content standards driven reforms, closely integrating intellectually challenging curriculum and assessments, believing that all students can learn and providing the opportunity for all students to learn."(p. 73-74) Fullan (1996), who believes that the attainment of student outcomes/expectations is the attainment of successful implementation, defines systemic reform as "clear and inspiring learning goals for all students, to gear instruction to focus on these new directions, and to back up these changes with appropriate governance and accountability"(p. 420) and believes that to increase the likelihood of systemic change occurring, the focus needs to be on increasing teachers' understanding of the curriculum so as to increase what teachers know and can do, on networking, and on the reculturing and restructuring within and between schools. Sparks (1998) also believes that it is the teachers' knowledge and skills that have the greatest impact on student outcomes.

The study by Miller, Drake, Harris and Molinaro (2000) on the implementation of the Common Curriculum, examined how teachers met the challenges of curriculum implementation, alternative assessment and outcomes based learning. This study also examined how the schools changed with respect to collaboration, role of the teacher, leadership and personal/professional development. This 3 year (1994-1997) study involved 4 elementary and 5 high schools chosen from a sample that consisted of 4 school boards, 191 elementary schools, 42 high schools, 108 000 students and 5 500 teachers. Each board in general chose two schools - one highly innovative school and one school that had few initiatives, and collected data from a wide variety of contexts, such as interviewing personnel from the schools and the boards, observation, and transcripts. The results were categorized under "old story" which deals with traditional or past practices, "present story" which deals with present practices and "new story" which deals with future change. Drake (1996, 1998) has also used this descriptive categorization, and found it helpful.

The study by Miller et al. (2000) was useful because the large size from which the sample was taken is likely to be a more representative sample than the present small study thus may help to increase the validity of the findings of this study. It will also help in the understanding of large scale change, hence will help understanding findings in the present study.

In the study by Miller et al. (2000) most of the findings were categorized under present story. A few teachers and administrators were working from an old vision of education (old story) and a few teachers had a vision about exploring the curriculum in new and different ways (new story).

The Old Story

The few education personnel that had an old vision of education saw little benefit to the Common Curriculum. They believed that subjects should not be integrated, they assessed students using mainly tests, and they felt that the outcomes lacked clarity and simplicity and teachers tended to use a few essential outcomes and long checklists to guide their work. These educators preferred to work alone and so there was little collaboration, and they saw their role as transmitters, not facilitators. There was little staff involvement or leadership by the principals, and professional development was either ignored or poorly planned.

The Present Story

The vision of most of the participants did not include the traditional subject-based curriculum and paper and pencil tests, but a current vision of education which included implementing the Common Curriculum. In the present story, teachers were managing to integrate the curriculum but only to a certain extent; teachers were evaluating using rubrics, and assessing students using levels, and teachers used the outcomes as a guide for what needed to be taught and learned. Teachers collaborated in groups both formally and informally, teachers saw themselves as facilitators of learning, and both administrators and staff were involved in the change process with administrators setting the agenda and facilitating change. Teachers valued principals and vice-principals when they were: "encouraging teachers to take risks; setting a positive tone in the school; being receptive to teachers' ideas; being visible in the school and not being away from school, delegating responsibility, and communicating clearly with staff" (Miller et al., 2000, p. 6). Professional development was seen as an ongoing process, with staff meetings in some schools being used for professional development but that the amount of professional development had decreased because of cutbacks.

The New Story

Teachers working from the new story saw the Common Curriculum as an opportunity to attempt new approaches and changes in their classroom and school. These were the teachers who were trying to effect a new vision of education. Teachers integrated the curriculum at the junior level the most effectively. Teachers were using a variety of assessment including paper and pencil tests, self-assessment, peer-assessment, observation, student's checklists, and conferencing. Teachers were working collaboratively including sustained planning with other teachers, students and parents, and teachers found satisfaction and positive rewards in working collaboratively. Collaboration also tended to include regular meetings as a team to plan. Teachers found that they learned from their colleagues. Teachers felt that their role was to address the cognitive, social, and emotional needs of the students. Many of the teachers saw themselves as leaders, initiating professional development activities in the school and acting as mentors. Principals encouraged teacher leadership. In the new story, professional development involved constantly learning on the job every day.

The old story, present story and new story show close parallels to O'Hair and Reitzug's (1998, as cited in Miller et al., 2000) comparison of conventional education model (old story) to the democratic model (present/new story) where the conventional model typifies "an isolated culture; disciplines; lectures and conventional teaching practices; traditional evaluation; factory model; administration as leaders; one shot professional development" (Miller et al., 2000, p. 9); and, the democratic model typifies "a collaborative culture; integrated, standards-based approaches to curriculum; community involvement; alternative assessment practices; shared leadership; teacher leadership; teacher as learner; ongoing in-house professional development; change perceived as continual; and positive attitude of educators" (Miller et al. p.10).

This study by Miller et al. (2000) brought to light a number of significant findings. Teachers were experimenting with the mandated changes and implementing the curriculum in their own way and contexts (Fullan, 1998b) by re-framing the Common Curriculum to make it work for the teacher as well as the student. Hargreaves (1998) states that when governments expect teachers to create their own understanding, and implement new curriculum or innovations, it will, in the end, lead to lower standards of learning. Teachers had a positive attitude towards the implemention of the Common Curriculum. There was a reculturing in the schools because of changes in curriculum practices such as collaboration, leadership roles and professional development, and this changed how the schools operated, specifically with respect to collaborative relationships. These collaborative relationships were seen by educators as having many positive rewards. A significant finding was that teachers were emerging as leaders and initiating professional development. Teachers were resilient, a characteristic of handling change (Conners, 1993) and thus positive change would most likely continue to occur. Finally teachers saw themselves as continual learners and collaborators. Senge (1990) states that the learning organization, the cornerstones of which are continual learning and collaboration, survives during changing times.

The study of Lafleur and Tucker (1997) was designed to determine the experiences of teachers implementing the Common Curriculum, Polices and Outcomes, Grades 1 to 9 (1995). The sample consisted of six competent and experienced teachers from grades 7, 8 or 9 who were curriculum leaders. This study of Lafleur and Tucker was chosen because like the previous study mentioned beforehand (Miller et al., 2000), examines teachers' experiences implementing the Common Curriculum, but the types of teachers used was dissimilar in the two studies.

Teachers identified five barriers to implementation: "physical obstacles, content coverage, attitudes of staff, uncertainty and stress, and time" (Lafleur & Tucker, 1997). All felt that the physical separation of grade 9 from grades 7 and 8 makes collaboration between teachers difficult. Also grade 9, being in a secondary school building, is better equipped with computers and science labs. All felt that the curriculum must be covered which made them uneasy, but they believed that students must be prepared content wise for high school. They viewed their colleagues as not being as interested in change as they were, angry, frustrated, and resisting change. All participants although optimistic were uncertain about what effective implementation entails, and uncertain about the future direction of education. The use of time effectively, efficiently and productively was a daily challenge, as there was never enough time for timetabling, planning, or organization and teaching of the curriculum.

Teachers defined five facilitators of change, which they favoured positively. These were as follows: "subjects vs quadrants; leadership and support, team teaching; input/control of change; attitude to change" (Lafleur & Tucker, 1997, p. 5) . The participants believed that implementation was assisted by student-centred integration of learning, support and understanding from school administrators and the constant help from consultants, their commitment to team teaching and to improving its potential. In addition, these teachers not only saw change as inevitable, and a part of their lives as professional educators, but they welcomed it and felt that they were a positive part of the change.

The beliefs and practices of the six teachers in this study help in the understanding of why the implementation of the Common Curriculum was successful. These included the following: attitude about students; attitude towards parents; the participants' attitude; teaching strategies; outcomes versus objectives; and assessment and evaluation. Participants commented positively about their students, helped their students to develop a positive attitude towards schoolwork and challenged students. The teachers supported parental involvement in leadership and curriculum issues, and felt that parents should always be completely informed about their child's progress. These participants possessed a positive, optimistic attitude and saw change as inevitable. Participants showed little enthusiasm for the traditional lecture methods, but instead used a variety of instructional techniques and groupings including small group work, cooperative learning and learning in pairs. Teachers emphasized what a student could learn and not what they are taught. All participants used a variety of assessments including the following: "learning logs, self-evaluation, checklists, interviews responses, solos, quizzes, tests, seat-work, portfolios, lab reports, peer evaluation in group work, standardized tests, and projects" (Lafleur & Tucker, 1997, p. 23). Assessment and evaluation were used to assist in the identification of the students' strengths and weaknesses, to provide feedback for corrective measures with the final aim of achieving what the student needs to learn.

Since completing the study, the authors Lafleur & Tucker (1997) have brought forth several rhetorical questions from their discussions (see Appendix 3). A number of questions are included here because of their potential relevancy to this thesis:

- *Why do some teachers situate themselves at the leading edge of this type of change?* Are they individuals who lead our thinking and cause change? Or, are they "super followers" who make politically, expedient forecasts and realize it's better to simply get on with it?
- *What is the change process here?* Are the teachers learning new strategies and internalizing new concepts? Or, are they simply adjusting their language to the new political milieu? What do they say when the tape is not running?
- *What is the most appropriate connection between assessment and evaluation and instruction?* While there is general openness to using a variety of assessment strategies;

making the seamless link with instruction is not always an easy transition. In addition, there is a sense of mystery about how judgements of student achievements are made.

• *Will curriculum integration ever be more than a "skin deep" change?* In the main, these teaches support the changes related to curriculum integration, but they speak the language of the traditional core disciplines of the latter 20th century. Is true integration a viable and realistic goal for all teachers?

• *Why are these teachers not working more collaboratively with others?* Are the teachers accepting only the changes that suit them and that they can handle by themselves? While there is evidence to support team teaching and co-operation with others, collaboration (in planning, staff development, organizing) was notable by its absence. Managing change seemed to be a personal responsibility. (p. 26, 27)

2.2.C Implementation of The Ontario Curriculum Grades 1-8: Science and Technology **(Ministry of Education and Training, 1998b)**

2.2.C.i The Implementation Process: The First Stages

This section describes what was done at the local level for teachers in the early stages of the implementation process to assist in the implementation of The Ontario Curriculum Grades 1-8: Science and Technology (Ministry of Education and Training, 1998b). The description of the implementation process below is primarily the result of discussions with M. Clarke, Lakehead District School Board, Member of the Implementation team from the Board Office , Elementary Resource teacher (personal communication, October 19, 1998), R. Pierce, Education Officer, Ministry of Education (personal communication, October 22, 1998), M. Strerz, Coordinator of Elementary Programs, Thunder Bay Catholic District School Board and I. Strachan, School Services Department, Technological Studies Consultant (personal communication, October 23, 1998). Theses individuals were all part of the regional team who were a part of the train the trainer model and were previously trained themselves by the provincial team.

The Ontario Curriculum Grades 1-8: Science and Technology was released by the Ministry of Education and Training in 1998. To relieve some of the burdens and difficulties associated with new innovations, teachers in Ontario from the Catholic schools met in the summer of 1998 and participated in discussions concerning the creation of resources to help teachers through this phase. The Northern Ontario Catholic Curriculum Cooperative (NOCCC) and the Ontario English Catholic Teachers Association (OECTA) collaborated on the curriculum resources packages for two strands: Life Systems and Energy and Control which were in the classroom by November 1998. The first of OECTA's teacher resources, Life Systems was authored by teachers from the Eastern Ontario Catholic Curriculum Cooperative (EOCCC). The resource package for Energy and Control was authored by the Central Ontario Catholic Curriculum Cooperative (COCCC). NOCCC and OECTA prepared the resource package for Structures and Mechanisms by March 1999. Teacher resource packages for the remaining strands were completed by spring, 1999. The development of these resources was funded by OECTA. The resources were meant to be used by teachers to support and provide tentative help in the implementation of the science and technology curriculum. Some of the features of each package typically include: hands on student activities and the expectations for each sub task, background information, list of references, the Catholic expectations, teaching/learning strategies, assessment tools and strategies, safety aspects, and how to adapt these activities to make them appropriate to their classroom (OECTA, 1998).

Graham Orpwood and Marietta Bloch from ASAP were contracted by OECTA to aid in developing the resource document *Implementation Planner: The Ontario Curriculum Grades 1 - 8: Science and Technology* (Ministry of Education and Training, 1998a). The final aim of this document was that it should be used by regional teams to train "experts" who would then train teachers within their boards on the implementation process of this new science curriculum. The development of this document was funded by the Ministry of Education and Training (MET) with contributions made by individuals and groups. This document was presented to regional implementation teams consisting of members from various school boards at a 2-day implementation planning workshop in Toronto. Some of the important issues discussed at the workshop included the following: the philosophy and intent of the document, the difference between activities and expectations, linking activities to learning expectations and assessment, planning for the teaching of knowledge, the role of science and technology, the importance of questions, what is effective science and technology teaching, identifying the issues and challenges, managing the challenges - stages of change, models of delivery, engaging the assistance of the broader science and technology community, the importance of safety, and the assessment of science and technology (Ministry of Education and Training). During the workshop, each regional team was given time to plan for the three days of inservice training that they would be providing for the school district teams.

The six member regional team from the northern region divided their region into two. Each three member regional team then spent three days training school district teams which generally consisted of 7 to 9 principals from each school board. The training focused on the implementation of the three process goals of science and technology education (Ministry of Education and Training, 1998b) with specific emphasis on the inquiry and design models. The school board teams then trained teachers for one-half of a day in September 1998. The agenda included a discussion on the goals, expectations, strands, topics of the science and technology curriculum document, and methods of assessment/reporting. Teachers had their first hands-on experience with the inquiry and design processes. The issue of resources and purchasing were discussed - money was made available for textbooks and some resources (software and lab materials).

The implementation process was a three to five year plan for most school boards. The two school boards in this region (the public and separate) had a three year plan, with the implementation of two strands by 1999, two more strands by 2000, and the final strand by the year 2001. Implementation included OECTA resource teacher packages, modules, inservice training which included information on the inquiry model and assessment rubrics, possible training of teachers during release days, and training after school. These inservice workshops emphasized the strands being implemented at the time but support was also provided for those without resource packages. Any other issues, questions or concerns were also discussed at these local teacher training workshops.

3 METHODOLOGY AND RESEARCH DESIGN

3.1 Problem

Because I am a teacher and my educational background is primarily in Science, I was very interested in the teachers' response to the introduction of the new Ontario Science curriculum in the elementary schools.

The questions which this research addressed dealt with the teachers' knowledge of the implementation process and their knowledge of, adaptations to and experiences with the introduction of the current elementary school Science and Technology curriculum. Particular emphasis was placed on examining how teachers developed science and technology concepts through inquiry and design, and the methods teachers used to assess student achievement.

3.1.A The Research Questions

The four major questions addressed by this study were:

1. What knowledge do teachers have of the implementation process?
2. What knowledge do teachers have of the new curriculum?
3. What changes have teachers had to make in order to adapt to the new curriculum?
4. What challenges has the new curriculum posed and what solutions have they found for these challenges?

3.2 Design and Methodology

Martella, Nelson, and Marchand-Martella (1999) define qualitative research as "Research in which the concern is with understanding the context in which behaviour occurs, not just the extent to which it occurs; the data are collected in the natural setting; meanings and understandings are reached by studying cases intensively; inductive logic is used to place the resulting data in a theoretical context" (p. 561). This research reveals the teachers' perceptions on the changes that have occurred and the challenges that they faced during the implementation of the Science and Technology curriculum, grades 1-8. This research was a preliminary, investigative, applied type research which did not allow for a development of a theory because the implementation process was only in its initial stages at the time of the data collection. Qualitative research was used because it was felt that qualitative research would permit the collection of rich descriptive data that would provide insight into the implementation of the science and technology curriculum.

3.2.A Type of Sampling: Purposeful Sampling

Purposeful sampling is not concerned with the representativeness of the sample and generalizing to the target population but is concerned with "selecting individuals that support a specific purpose.... in order to complement the goals of the study" (Schloss & Smith, 1999, p. 104). The results from this type of sampling cannot be generalized with confidence to other individuals, but "they simply illustrate a method or trend that may be evaluated with other individuals possessing characteristics similar to individuals in the sample" (p. 107). A two by two block design was used. One variable considered in the selection process was the teachers' experience in science. This was divided into two levels: 1. teachers with science experience (specialist in science, a degree in the "sciences"), and 2. teachers with no post-high school science background. The other variable considered in the selection process was the teachers' years of experience. This also had two levels: 1. teachers with at least five years teaching experience, and 2. teachers with little or no teaching experience (i.e. less than five years teaching experience). The original intent was to select eight Grade 8 teachers from the local pool of teachers in the Thunder Bay Catholic District School Board, two in each square of the block design. Unfortunately, there were not enough teachers from the one Board that were willing to participate in the study so the Lakehead Public Schools was also included in the study. There were nine teachers willing to participate in the study: two were inexperienced specialists, two were experienced specialists, one was an inexperienced nonspecialist and four were experienced nonspecialists. Although it would have been desirable to have a balanced distribution, this study was not intended to be a statistical study. It was felt that the variables of specialization and experience would potentially influence some responses, and so a variety of backgrounds in these areas was felt to be important to the validity of the study.

3.2.B Type of Research: Case Study Research

Yin (1984, p. 20) states that the case study has a distinct advantage over other research strategies when a "how" question is being asked about a contemporary event which the investigator has no control over. In this thesis the fundamental question to be answered was, "*How are Grade 8 teachers dealing with the introduction of the new curriculum?*", a contemporary issue over which I have no control.

Thus, the qualitative research method of case study was chosen based on my role as a researcher, the purpose for conducting the research, and the naturalistic and unobtrusive methods which were used to draw conclusions (Schloss & Smith, 1999).

> Case studies allow you to focus on a single instance of a current phenomenon in its total context.... A case study allows you to observe events as they unfold and to interview those who participate in these events. Typically, case studies involve multiple data sources, including discussions with the participants, direct observations, and analysis of written documents (p. 87).

Four different cases were specifically chosen using categories presence/absence of science background, and teaching experience in order to compare and contrast the data for diversity and/or generalizability. In order to understand the subjects' points of view and experiences, I sought the multiple interpretations and realities of the science teacher in this the phenomenon of the implementation process.

3.2.C Types of Questions: Standardized Open-ended Questions

The standardized open-ended interview consists "of a set of questions carefully worded and arranged with the intention of taking each respondent through the same sequence and asking each respondent the same questions with essentially the same words" (Patton, 1990, p. 285). This systematic and thorough method of interviewing decreases the effect of interviewer bias, increases the comparability of the responses and the subsequent ease of data analysis, and provides rich, descriptive data. The standardized nature of the open-ended interview does not allow for the unforeseen, and for examining individual differences and unique experiences (Patton). The questions that were used were singular, open-ended, neutral and clear. The five types of questions used werew as follows: experience/behaviour questions, opinions/values questions, feelings questions, knowledge questions, and background demographic questions. The sequencing of questions was similar to the preferred method of Patton (p. 294), progressing from the least difficult descriptive question to the most difficult knowledge type question requiring factual recall (which may be perceived as threatening). Collecting factual data on subjects was placed first because of its routine nature.

The questions below focused on the following areas: factual data on teacher's background, teacher's knowledge of the implementation process, what assistance have teachers received from administration, the board, and the principal, the advantages/disadvantages of the new curriculum, what changes have occurred in the science content and methods of evaluation, how are teachers developing the students' questioning skills, how are teachers developing and assessing the skills of inquiry and technological design, types of evaluations used to determine the students' conceptual skills, comfort level with the use of achievement levels, role of the teacher, and concerns of the other teachers.

The questions are divided into two interviews each approximately one hour long. It was felt that conducting the two interviews over a reasonable time would result in a more focused interview .

3.2.C.i The Interview Questions

Interview 1

Name: ?

Teaching experience: Years teaching?
Years at present school?
Specialize in Science or all subjects taught?
Years teaching Science?

Science Background: Undergraduate degree?
Subject Specialist?

1. Have you started to implement the new curriculum?

Probe: Which aspects have been implemented?

- which aspects have been given more attention?
- which strands are you implementing and planning to ....?
- how are you filling the remaining time (if covering only two strands)?
- how many times per week do you see each science class?
- how long is each period?

2. What assistance have you received from administration in the implementation of the science curriculum? - both directly and indirectly

- textbooks - sufficient, scope of coverage of curriculum, is a variety used
- handouts, booklets, resources, STAO
- lab equipment
- PD (Professional development activities)

3. What do you see to be the advantages of implementing the new curriculum?

- compared to the old curriculum
- better continuity
- more structure

4. What do you see to be the disadvantages of implementing the new curriculum?

- sufficient space/resources for labs
- support structure
- is there enough time to cover all aspects of the curriculum
- your views on standardised testing

5. What changes have occurred in the content of instruction?

- would it help to have course profiles from the board?
- do you believe that being qualified in science is an asset?

6. What changes have occurred in the means of instruction?

Probe: What are your feelings about your ability to develop the inquiry and design skills in your students?

Probe: How are you fostering students' ability to construct the desired inquiry method of learning?

Probe: How are you fostering students' ability to construct the desired technological design method of learning?

- How are you fostering students' ability to develop their questioning skills - and is there enough time to do it all?
- Is there more or less structure in your classroom?

7. What changes have occurred in the methods of evaluation?

- rubrics and development of
- self and peer evaluation
- who should have input

8. What do you know about the implementation procedure for the new curriculum?

Probe: What is the time frame for its implementation?

Probe: Where is the implementation process at the present time?

Probe: What do you know of what has been done in the past?

Probe: What do you know of what is going to be done in the future?

- So at the end of which school year will the science curriculum be fully implemented?
- Is this a reasonable time frame?

Interview 2

1. What professional development activities have been planned (long/short term training) to assist in the implementation of the science and technology curriculum?

2. What feedback have you received from parents about the present science and technology curriculum?

3. What do you think are the main concerns of the other teachers in the schools with respect to the implementation of the science and technology curriculum into their classroom?

4. What are your main concerns about the implementation of the science and technology curriculum?
   - is contact time between you and your students sufficient to cover all 5 strands in 10 months? Is this a realistic expectation?

5. What could the board do to enhance the implementation process?

6. What could the principal do to enhance the implementation process?

7. What do you see as your role in the implementation of the science and technology curriculum?

8. What is your opinion concerning the use of achievement levels in your methods of assessment?

   Probe: In what ways have you used the achievement levels in assessing the knowledge and skills expectations of the science and technology curriculum?

9. What types of assessments are used to judge and analyse the skills of inquiry and design?

10. What types of evaluation are used to judge and analyse the conceptual skills?

11. At this time, is there anything else that you would like to add so that others might have a better perspective of the implementation of the new elementary school science curriculum?

3.2.C.ii Research Design

Table 15, below, relates the interview questions to the four main research questions investigated in this study.

Table 15

Relationship of Interview Questions to Research Questions

Research Question	Interview Questions (a,b)
1	(1,1), (1,8), (2,1)
2	(1,5), (1,3)
3	(1,6), (1,7), (2,8), (2,9), (2,10)
4	(1,2), (1,4), (1,5), (1,6), (1,7), (2,2), (2,4), (2,5), (2,6), (2,7), (2,8), (2,9)

Note: (a, b) - a represents interview "1" or "2" and
b represents the question number within that interview

Research questions "1" and "2" concerning the knowledge teachers have of the implementation process and teachers' knowledge of the features of the new curriculum is answered by only five of the interview questions. Most of the data collected from the interview questions answered research questions "3" and "4" concerning the changes teachers had to make, and the challenges posed and solutions found in implementing the science curriculum.

3.2.D Ethics

Participants must always be protected in research studies. The benefits must outweigh the potential for harm to the subjects. Bogdan and Biklen (1998) state that "In negotiating permission to do a study, you should make it clear to those with whom you negotiate what the terms of agreement are and you should abide by that contract" (p. 45). Two predominating issues of informed consent and risk assessment are in place to protect human subjects. The ethical concern of informed consent is to ensure that verbal and written consent will be gained from the respondents for their voluntary participation in the research study. The nature of this study was explained to the subjects and they were informed that they were free to withdraw at any point of the research. The ethical concern of risk assessment is to ensure that there is little risk to the participants, and that their identities will be protected. The ethical concerns that were addressed in this study included: the protection of identities, treating subjects with respect, not lying to subjects, seeking their cooperation, making clear and abiding by the terms of the agreement, and telling the truth when the findings are known. If problems or questions arose, the individuals were encouraged to contact my thesis supervisor, Dr. A. Bartley, at Lakehead University. The research was approved by the Lakehead University Ethics Committee and the two school boards before interviews commenced.

3.2.E Data Collection

A comfortable, safe and convenient location was chosen for the tape-recorded interviews, generally the teacher's classroom. The subjects were given a copy of the questions to examine so as to gather their thoughts before each interview. Prior to the start of the first interview, I briefed the participants on the purpose of the study, reminded and assured them that the information provided would be kept strictly confidential, that their names would be changed on the transcripts to protect their anonymity, that their participation in part or in full was strictly voluntary and highly valued, and that they were free to withdraw from the study at any time. The first interview was typically 1 to 1½ hours. The second interview consisted of more descriptive, analytic questions than interview one and so tended to take a little longer, 1½ to 2 hours. The two interviews were usually held one to two weeks apart although in one case they were done in sequence the same day and in another they were about one month apart.

3.3 Data Analysis

In this study, the case studies were compared and contrasted. After the data was collected, I attempted to identify prominent issues and frequent events and use them to create coded categories which were assigned to units of data. "Units of data are usually paragraphs in the field notes and interview transcripts, but sometimes they can be sentences or a sequence of paragraphs" (Bogdan & Biklen, 1998, p. 183). The coding system covered all substantive areas of concern but reduced the data for more efficient analysis. Major codes and subcodes were used. "Major codes are more general and sweeping, incorporating a wide range of activities, attitudes, and behaviours. Subcodes break these major codes into smaller categories" (p. 183). An inductive analysis approach was used to search for codes, themes, patterns and relationships in my quest for finding the natural and implied variation in the data. I analyzed for participant generated typologies used to explain their world, and I generated my own typologies which were implied by the data. To increase the validity of the results an analysis across all the cases was done on all interviews. Each paragraph, sentence or group of words within the data was marked with the relevant coding category. "Often units of data will overlap and particular units of data will fit into more than one category" (p. 183). Therefore, more than one coding category was assigned to overlapping data.

In qualitative research it is important that the results be reliable. Bogdan and Biklen (1998) state that "qualitative researchers tend to view reliability as a fit between what they record as data and what actually occurs in the setting under study, rather than the literal consistency accross different observations" (p. 36). This research addresses reliability in two ways. First, there is overlap between the responses to questions so that consistency of response may support the reliability of the data. In addition, teachers' responses in this research were compared to and were found to be similar to responses of teachers in similar situations published in the open literature.

4 PRESENTATION OF THE FINDINGS

4.1 The Sample

The sample consisted of nine Grade 8 teachers who completed the open-ended interviews. They will be identified by the following pseudonyms: AY5, BY5, CN5, DY6, EY6, FN6, GN6, HN6, and IN6 and when direct quotes are used, they will be referred to as such. Two specific characteristics of the sample, notably teaching experience and science background are noted. A "Y" as the second letter in the pseudonym indicates that the teacher has a university degree in Science, while "N" indicates otherwise. The number in the pseudonym indicates the years of teaching experience: 5 indicates less than 5 years, and 6 more than 5 years. The data indicates that three teachers had five years or less teaching experience (AY5, BY5, and CN5) and that four teachers had a science degree (AY5, BY5, DY6 and EY6). Table 16 indicates the specialization and teaching experience of each participant in the study.

Table 16

Specialization and Experience of Teachers in the Study

	Experience	
	Less than 5 years	More than 5 years
Not Science Specialist	CN5	FN6, GN6
		HN6, IN6
Science Specialist	AY5	DY6
	BY5	EY6

Teacher AY5 had a B.Sc. in Natural Science and had been teaching as a Science specialist for 1 year. Teacher BY5 also had a B.Sc. in Natural Science and had been teaching as a Mathematics and Science specialist for 2 years. Teacher CN5 had a B.A. in Social Work and had 4 years teaching experience teaching all subjects. Teacher DY6 had a B.Sc. and had been teaching for 10 years, 7 of which had been as a Science specialist. Teacher EY6 had a B.A. in Geography and an Honours B.Sc. in Biology and had been teaching 24 years, the last 5 of which were as a Science specialist. Teacher FN6, the most senior teacher, had a B.A., 35 years teaching experience of which the last 20 had been as a Science Specialist. Teacher GN6 had a B.A. and 10 years experience teaching all subjects. Teacher HN6 did not have a university degree and had been teaching all subjects for 30 years. The final teacher, IN6, had a triple major B.A. in the Social Sciences and had been teaching all subjects for 30 years.

The data indicates that the sample included teachers with various "science" degrees, and teaching experience ranged from one year to thirty-five years at the time of the study. Four of the teachers felt that a science background eased the implementation of the science curriculum, while the other five teachers felt that experience or familiarity with the material was an important factor. Some teachers taught mainly science, while other teachers taught one grade and had the same students for all subjects.

4.2 Teacher Responses to the Interview Questions

4.2.A Interview One

Data is presented in this section for questions one to eight. The common trends, patterns and elements that the teachers express are discussed using direct quotes. Since nine teachers participated in the interviews, the term "majority" will be used as a convenient term to indicate that five or more express a similar opinion or view. The word majority, in this context, is not meant to indicate a general statement that can be extended beyond this group of teachers since a sample of only nine teachers is too small for meaningful general conclusions about the entire population of teachers in Ontario.

Question #1 Have you started to implement the new curriculum?

This interview question is aimed at addressing some of the issues relating to the research question 1: What knowledge do teachers have of the implementation process?

Analysis of the data shows that teachers are at various levels of the implementation process with respect to the strands implemented - a range of two(part) to five strands (all). The boards' plan is for the schools to implement two strands in the first year, four strands in the second year and five strands in the third year. The interviews were done in the first and second year of the implementation process and this explains why the teachers had implemented various numbers of strands. All teachers are on schedule with three teachers in their second year of implementation aiming to cover all five strands and one teacher in the first year of the implementation process covering three strands.

Teachers BY5, FN6 and GN6 are three of the teachers that are planning to implement all five strands. Teachers FN6 and GN6 are two experienced teachers (>20 years) who felt that familiarity with the material leads to ease in ability to implement all 5 strands. Teacher BY5 is a teacher with little experience but a science specialist.

> Actually we have implemented the new curriculum fully. Even though we didn't have the requirements to do all five strands last year we did them. And we're doing all five strands again this year. (FN6)

The time spent on science per week varied with one teacher allocating 80 - 120 minutes per week, three teachers 120 minutes, two teachers 150 minutes and one teacher 160 - 180 minutes per week. Note that these are approximate times and will have an impact on the number of strands implemented and the degree of depth of coverage of the curriculum. Teacher CN5, who had the least teaching experience and who is not a science specialist, spent the least time teaching science.

In summary, all teachers are implementing the new curriculum and all are on schedule. Three teachers were planning to cover all five strands, two of these teachers are experienced in years, and one is a science specialist with little experience. Also, the time spent on science varied from 80-160 minutes per week with the teacher with little teaching experience and who is also not a science specialist spending the least time teaching science. This question thus partially answers the research question on teachers' knowledge of the implementation process.

Question #2 What assistance have you received from administration in the implementation of the science curriculum? - both directly and indirectly

This interview question is aimed at addressing some of the issues relating to research question 4: What challenges has the new curriculum posed and what solutions have they found for these challenges?

The common themes are classified as (i) textbooks (ii) handouts, booklets, and resources (iii) lab equipment and (iv) professional development/in-service.

Textbooks:

Only one teacher reported not having textbooks in the classroom due to financial reasons:

> Basically there has been no assistance unless assistance means spending some money on some of their required equipment to run a science program, but most of the money was spent in the primary/junior division, and other than that, I have been basically told by administration that no there is no money for new textbooks, you get to keep using your ten and twenty year old textbooks .... (HN6)

Of the remaining teachers, two have two or more students sharing a text due to budget constraints and two teachers rarely use the assigned text.

> I've been talking with my peers and planning as divisions, one of our largest concerns is the finances available to support the curriculum in terms of resources. Finding the money with everything else that we need to find money for in the school. Finding textbooks, purchasing , science equipment, science, I believe science should be hands on. Science doesn't happen in a textbook. ...... Buy all the student books I mean we don't have one for every student, we have perhaps twelve or fifteen, so it's one book for every two or three students. Which, for how I do science in the classroom, which is hands on, its turned out to be fine.(GN6)

Handouts, booklets, resources:

All of the teachers received resources other than texts from OECTA, STAO, and the publisher Nelson, which have been used as supplementary material to assist in the design and implementation of lessons in the classroom, in the assessment and evaluation of the student, and in the preparation of labs. Some of the teachers are not using the material because of lack of time, or because the resources are not seen as necessary:

We do have some material in the staff room. Quite frankly, I haven't looked at it because it's not, again, a need of mine. And I believe some of it came from the separate school system, or from OECTA. And some of it is from our Board and I believe some of it is from STAO. So I know there is some but I am doing all of the intermediate science in our building, so it's not something that I am worried about nor I'm aware that it's a problem....No, I can't see it as an issue here. (FN6)

Others find the extra resources useful:

Some [were]. We bought some of the science modules, the big binders and the small books that meet, that were written directly for the new curriculum. They are really good. I like them. We use those to supplement, to design, to work around, it helps to make sense of the experiments that go on in class ......I guess as we slowly implement this.... I [will] have all of the strands, all of the teachers' manuals and all of the student books for all of the strands.(GN6)

One teacher finds the material useful but would prefer a summarized version:

We have received some things from the Ontario Catholics Curriculum Cooperative and we are receiving them as they come out. And then we use them to supplement what we already have. We use some things from STAO. But in terms of anything that has come from our Board directly, no, there doesn't seem to be any initiative to, or at least I'm not detecting any. .....Yes. I find the cooperative [useful], though, there is too much time spent in the preamble, in the introductory literature. It's a bit much because at this time, with every one's workload increasing and with all these new documents that we all have to absorb, I need something that I can look at and not have to spend a great deal of amount of time, going through in order to basically find the meat. (DY6)

Lab Equipment:

Only two teachers, BY5 and FN6, felt that they have a lot of equipment:

> As far as lab equipment, I'm new to this school this year, and I haven't checked out the entire science cupboard. They spent quite a bit of money last year on science equipment, so there's quite a bit up there. (BY5)

The majority of teachers have limited lab equipment:

> To give you an example, I had to teach an optics unit and I have no lenses, I have no mirrors, there is no materials here at the school so we had to improvise with bags of water, just trying to make our homemade things. Administration is very supportive in recognizing that the materials are not here, but their hands are tied with whether there's money in order to purchase them. .... The other thing that happened last year, was one day the principal had a list of materials, a list of science resources, and said, alright we need to put an order in by tomorrow. Sort of the money is here, the government has given us the money but we have to spend it by tomorrow. So what do we need and so it was strictly people saying, I think we need this, I think we need that, and obviously some things did not get looked at, because there are certain strands that we don't have the materials for. (CN5)

Three teachers stated that the school should have a science lab. Teacher IN6 stated why very succinctly:

> Actually, as far as I'm concerned, every elementary school should have a science lab that can be booked. It would be the ideal situation where you would actually have a science lab that could be used and you'd book it out and do experimentation and gas setup, the only thing is you would have to make sure that there was somebody who had the expertise to show people how to use it properly. (IN6)

Professional development (PD)/In-servicing:

The professional development included workshops organized by the board, OECTA or by Nelson and ranged from ½ day to 1 day. Teachers attended 1 - 3 workshops.

One teacher feels that the board provided sufficient in-service:

> I am sure that the Board has sufficient P.D. activities to meet the needs of most people. Like I said, it's not something that I have been most concerned about, because it's not something that I really felt that I needed that badly. (FN6)

Another teacher feels that although in-service has been limited with respect to the new curriculum, workshops will follow as the need arises:

> In-service. Not a lot in the new curriculum, but the other one, because this one hasn't been in effect that long, but the curriculum before, there was, oh I bet you, fifteen various workshops. So what will happen is, as the needs arise, specific needs arise, then you'll find that the workshops will follow suit. (IN6)

The feeling by the majority is that more PD is needed:

> My concern, in terms of, support, is in-service for implementing the science. I've been to one - one workshop was made available to me that I was aware of anyhow. I think that if my personal belief on this, on administration and administration I'm thinking ministry of education provincially on down, is if you are going to have a new curriculum, you need to support it with in-service .... during school time. And I haven't seen enough of that for my liking. (GN6)

In summary, the assistance that the teachers received from administration varied widely: from administration being very supportive but no money to very supportive in all respects, to not a lot of assistance from administration. The responses to this question were un-related to the factors of interest to this study - experience and specialization. This question thus partially answers the research question on the challenges teachers faced and the solutions found in implementing the curriculum.

Question #3 What do you see to be the advantages of implementing the new curriculum?

This interview question is aimed at addressing some of the issues relating to research question 3: What changes have teachers had to make in order to adapt to the new curriculum?

The major trends observed in the data include advantages of: better continuity, more structure, and standardized expectations. Included in this, teachers discussed the standardization of the report card across the province.

More Continuity and Structure:

All of the teachers interviewed who responded to the probe concerning continuity and structure felt that there was more continuity and structure:

> ...But, I look at how I do science, I've been teaching forever, this is my tenth year full time .... I think I remember how I started, I remember how science got taught, and it was really hit or miss I think. .....I think its much more systematic. I think you get better coverage. I mean, a kid should be able to change a school and get most of the grade seven curriculum. Yeah they might miss a strand cause one school did a different strand at a different time, but, you know, they're not completely missing the boat. (GN6)

Standardized Expectations:

The six teachers that commented on the standardized nature of the curriculum all felt that it was an advantage. Three also had positive comments about the standardized report card.

> ...I also think it's an advantage having students transfer in and out of your class. When I've had a few students transfer out of my classroom, [and] its nice to be able to say, okay we've done this strand, we've already done this unit, ...and when a new student comes into my class, I can say, alright, which strands have you done, and then its much easier for me to make sure that the student gets what they need for a good Grade 8 curriculum.
> .. The joke is that teachers love teaching dinosaurs so kids had a dinosaur unit in almost every grade coming up because the teachers really liked teaching that, whereas now it doesn't matter what you like teaching. This is what you need to teach and this is what they are going to get in grade seven, this is what they are going to get in grade eight, and I think that's very positive. (CN5)

> ***Standardized Report Card:***
> ....the new report card, for all the complaining about it, is the same across the province. ....but the bottom line is when you get a report card from a student outside of your jurisdiction and you read it, it makes sense. Because you're using the same one. So I like the consistency. (FN6)

Two teachers feel that high school science teachers now have a clear expectation about the prerequisite knowledge/skills of the elementary Grade 8 science student:

> They will all have covered it. And that augers well for, I would think, should make it easier for transition into high school because high school teachers no longer have to worry about whether kids in a particular school have done a science program, and if they've done it, what kind of a program have they done. (FN6)

One teacher found the more challenging nature of the new curriculum to be an advantage:

> I like the fact that it's a more challenging curriculum. I like the fact that some of the Grade 9 concepts have been brought down to the Grade 8 and some of the 8's have been brought to the 7's. I think that's good. I think our old curriculum was a little soft. I think things like cell theory can be taught in Grade 8. (DY6)

In summary, most science teachers are aware that the continuity of the curriculum from Grades 1 to 8 means that there is little overlap from grade to grade. Most teachers also see the positive aspects of the increased structure of the curriculum not influencing students transferring from class to class or from school to school, that the curriculum is laid out point by point, and that there is no guesswork. The standardization of the curriculum across the province and the consistency of the report card also makes sense to the teachers as all students are doing the same thing and their progress is reported the same way. All teachers that responded to this question, responded in a similar way. Thus no relationship was found between their answers and the two factors of years of experience and specialization. This question thus partially answers the research question on the changes teachers made to adapt to the new curriculum.

Question #4 What do you see to be the disadvantages of implementing the new curriculum?

This interview question is aimed at addressing some of the issues relating to research question 4: What challenges has the new curriculum posed and what solutions have they found for these challenges?

The common trends include the following: insufficient time, lack of support structure, complex curriculum, lack of resources for labs, and negative views on standardized testing.

Time and Challenging curriculum:

Although one teacher made no comment (DY6), all of the other teachers state that there is insufficient time to cover the entire curriculum because of the magnitude and complexity of the expectations that need to be covered, and the time is influenced by the ability of the class as a whole. As a result the teacher may cut corners or "water down" the curriculum:

> I'm not sure how much study was done on taking some of the concepts, for example, let's say optics again, and sort of, determining whether or not it was age level appropriate. ...Again, we have to be careful that it's not frustrating them more as opposed to challenging them more. A lot of the material, I think, in that specific unit, is very difficult for the students to understand and like I said, it's probably more frustrating than challenging. A good teacher will take them and sort of enable her students to understand the core concepts but my guess, is that in most cases they will have to water it down a little bit.(EY6)

> ...the other disadvantage was if you want to do it right,.... there isn't enough time. You run out of time very quickly,.... There's no possible way that I can go through and check off every expectation ... I think the more familiar we get with the curriculum, the easier it will be. (CN5)

Support Structure:

Seven teachers discuss the lack of support seen as necessary in order to maintain continuity and to teach and implement the curriculum effectively. Teacher's needs varied from wanting support material for all strands to only a few specific strands:

> ....it would be wonderful if the Ministry would put out lesson plans and actual unit plans. We have, there was a York university document that we have that has some lesson plans and there is the Edutech science and technology curriculum.... but, it doesn't cover all areas of the strands, and some strands are more sparse than other strands. ...I mean, it's a process, and it makes life so much easier if part of that process is in place for you already. So anything like that (hands on activities, lesson plans, worksheets, etc.) would certainly be appreciated. (CN5)

In some cases support was obtained by networking with other teachers.

> ....we get together in divisions and we plan units. We borrow units from other people that have may have gotten together at their school and written them, and we share that way. (GN6)

Lab Resources:

Six teachers state that the lack of resources to complete labs affects the "hands-on" nature of the curriculum and this also affects the degree of implementation of all of the expectations:

> And have all the equipment so that small groups could do it instead of two or three really large groups. I think more learning would take place and we would cover more. Sure, resources are very important. ...My concern is having the actual physical equipment. That's where I find the challenge more than anything else now. (GN6)

Space:

Three teachers stated that there is no science lab and there is insufficient space to carry out science labs in a regular classroom. They make do by rearranging the room, but this is time consuming:

> [About having a Science lab.] I know where the lab is, I can go, that can be set up. The

students can come in and we can go to work, we don't have to go dragging things out, setting them up, rearranging the room, and then taking it all apart again before we can move on to something else. ... I think that would help a lot. (GN6)

Standardized Testing:

The majority of the teachers feel that with the standardized curriculum, there is a potential for standardized testing in the future and that the negative aspects outweigh the positives. Teachers are concerned that the results do not always show the student's true ability and that the results of the test may become a selling tool for the school.

In summary, most teachers are saying that they would like more resources to help them to implement their lessons, their labs (materials and space), and their assessments and evaluations. The curriculum is also seen by most teachers as time intensive, and challenging for the average student. Most teachers view the results of standardized testing as potentially casting an unfair light on the student, the teacher, and the school. The responses were unrelated to the factors of interest to this study - experience and specialization. This question thus partially answers the research question on the challenges teachers faced and the solutions found in implementing the curriculum.

Question #5 What changes have occurred in the content of instruction?

This interview question is aimed at addressing the issues relating to research question 2: What knowledge do teachers have of the new curriculum?

Six of the teachers, at least one from each category, feel that the curriculum is being introduced to the students earlier; some teachers are specific as to which concepts are being introduced earlier, others simply describe their perceptions in broad and general terms. These teachers also feel that the content is more specific, detailed, knowledge based, and/or complex. Two teachers, both specialists one with more than 5 years experience, made no comment. One experienced , non-specialist had not made any changes due to lack of equipment and training.

Content:

I think the content...... it is more specific. I think in a lot of areas, the content seems to have, the bar seems to have been raised somewhat, that our expectations have risen, the benchmark is higher, now, I hear some of the junior teachers saying, man, I've got to teach some of this stuff, they used to teach that in grade eight. And I'm like, yeah, maybe they did. (GN6)

One teacher feels that no changes have occurred:

Well as far as I'm concerned nothing has really changed because I'm still working with the same stuff I've had for years. There might be slightly more activity based than the good old days, of here read this, answer these questions, there's more, a lot more activity stuff than that. In terms of the last ten years , no, there is no change. ...the expectations are based on kids having done it for five years before, and they haven't yet. Like I'm still getting grade sevens and eights, who basically haven't done this curriculum. And for the same reasons that I haven't been doing it for the lack of equipment, lack of training, lack of information. ...No, you can't make that jump into the new curriculum until the kids have a, you know, what came before.

...I guess it comes to the argument where you, where teachers deal with all the time, where "Are you teaching the subject or are you teaching the kids?" Especially with this school where kids who have very little support at home or you're dealing with kids who may have been exposed to the curriculum but haven't learned it. So you take there from where they are, you try to adapt what's in the new curriculum to what you've been doing, get as close as you can with it, you do the best you've got, with what you've got, and what we've got isn't very much. (HN6)

One teacher feels that very little change has occurred. The topics covered are the same, but are now taught in lower grades:

You know the truth. Not very much. And I'm speaking only for this particular school. We did a lot, an awful lot of the same stuff as is in the ministry document now, except we tended to call it different things. There's a unit in here that deals with optics. That's our old light unit. ... But in terms of the actual topics, there is the optics unit in grade 8, we used to do that as a light unit. We always did heat. We used to do an electricity and magnetism unit in grade 7 and that's backed up to grade 6. The mechanical efficiency and structural strength and stability units in grade 7 and 8, we always did something of that nature. We didn't call it that. We might have called it building towers and bridges, or something like that. But we always did that kind of stuff. The earth's crust. And we used to do a space unit which is now backed up to six as well, but we used to do that as an astronomy unit. Water systems is perhaps the one real new one. (FN6)

Of the three teachers with little experience, one of the two specialists and the non-specialist feel that course profiles would be helpful. The remaining specialist did not comment on the helpfulness of course profiles. Only one of the experienced teachers commented on course profiles and they did not see the usefulness of course profiles:

> That [course profiles] streamlines the curriculum that way when it gives you some more guideline. That would be a timesaver as well because it does give you an idea as to what's expected, not what's expected but how to go about meeting those expectations, by giving you ideas. You know, even with the science background, I find myself having to, not relearn the material but finding myself enough time to get comfortable with it. ... So that's, with the course profile I would save myself time in planning because I had sort of set out, whereas I would spend more time getting the actual content, in that way. (BY5)

> So I mean, profiling, course profiles, I guess they are okay, in some respects, but I don't know if you can always cover everything in the order. I don't know if you can do things in order. Again, if we talk about borrowing resources, maybe I have to do this now, because this is when the resource is available. ... So I, I don't know about profile, I like the curriculum the way it is laid out. (GN6)

Qualified in Science:

Probe: Do you believe that being qualified in science is an asset?

Three of the teachers say that being qualified in science is a definite asset, a fourth teacher says that teachers need a good science background. A fifth teacher says yes it is an asset, but it is not necessary - experience is necessary. A sixth teacher says yes it is an asset but for one subject only and that it is his 20 years of teaching science that is important. Of these six teachers, two had a degree in science and these two teachers see this as an asset. All six teachers that commented on this issue said that being a specialist is an asset but three of these teachers specifically said that their years of experience teaching science is also an asset:

> So if you had a science degree that would help you with that one subject, but it wouldn't do much good for you in English, or history. So an elementary teacher in effect, in most instances, has to have a very broad knowledge of the entire curriculum package. ....Oh (teaching) science for at least 20 (years). That's a huge advantage, there is no question about it. (FN6)

In summary, the majority of teachers feel to varying degrees that some of the concepts in the curriculum are being introduced at an earlier grade and are thus seen by the students as more complex and challenging. The content is also more detailed, and contains more theoretical knowledge. The well laid out expectations for each grade make it clear to the teacher what needs to be taught by the end of each grade and this is seen as positive. Two out of three inexperienced teachers felt that course profiles would be useful. The one inexperienced teacher that did not comment on this issue was a science specialist. The majority (six) of the teachers feel that having a science background is necessary to teach science well as the teacher has the core knowledge and skills and will thus be familiar with the grade eight science material. The majority of the teachers feel that being qualified in science is an asset. This question thus answers the research question on teachers' knowledge of the science curriculum.

Question #6 What changes have occurred in the means of instruction?

This interview question is aimed at addressing some of the issues relating to research questions 3: What changes have teachers had to make in order to adapt to the new curriculum? and, 4: What challenges has the new curriculum posed and what solutions have they found for these challenges?

This question examines how science is being taught. The Ontario Curriculum Grades 1-8 Science and Technology (1998) clearly states that the role of teachers is: "Teachers are responsible for developing appropriate instructional strategies. ...and a variety of teaching approaches. ....Teachers will provide as many hands-on activities as possible since the inquiry and design skills .... must be taught and learned through experiences with concrete materials." (p. 6) and that one of the goals of science and technology education is: "- to develop the skills, strategies, and habits of mind required for scientific inquiry and technological design.." (p. 4). Teachers answered this question with respect to how they are fostering students' ability a) to construct the desired inquiry method of learning b) to construct the technological design method of learning c) to develop their questioning skills d) any broad/general changes and lastly e) whether there is more or less structure in the classroom.

Broad Changes:

The broad changes were unique to each teacher with no correlation shown to the two variables years of teaching experience or specialist in science . One teacher finds little difference from the old curriculum except that it is a little more involved, while two teachers talk about the increased use of the internet. One teacher uses more direct teaching, while the majority of the teachers allow learning to occur in small groups. Teachers allow students to design their own labs. One teacher will occasionally do a teacher centered investigation. One teacher states that he is increasingly applying science to the real world.

> Also, like with the cells, we had cloning like week, and my lesson turned into a classroom discussion on cloning. Once I give them the background, we just end up talking about it and asking questions, and you know, what if they had done this, those kinds of things, just to get them thinking. They didn't realize that we were actually doing the lesson I had planned, but just differently. ...The discovery channel is a very popular resource. On TLC or discovery I saw this. And they'll let me explain more of it. So it means I can do those sort of things every once in awhile. The internet as well. (BY5)

> Well you know the funny thing is, I said, you don't stand at the front of your classroom and you don't always have to have a paper product. But when I stop and think of how many minutes I get to sit at my desk during the day because the kids are working, it's almost nothing. The teaching is all taking place in small groups and one of the reasons, other than the fact that it is better for science and stuff like that, ... is because they help

> each other. It's amazing how much kids will learn from other kids. ... But I find that they really help each other. It makes for a bit noisier classroom.(FN6)

Inquiry Method:

Teachers' discussion on how they are fostering the students' ability to construct the desired inquiry method of learning varied considerably. Implementation ranged from non-implementation (doing little with inquiry method because it is overwhelming or, haven't really implemented it yet or, it is not feasible but they are doing more labs) to partial implementation (slowly coping with the inquiry method but students not there yet as they need to be taught and re-taught) to complete implementation (always done many inquiry based labs with students in the past or, now uses it - does open-ended labs). All of the experienced teachers are continuing to teach as they have taught in the past. Four of the six experienced teachers feel that they have always been fostering the inquiry method of learning, and the other two experienced teachers appear to unwillingly implement the inquiry method in their classroom. Although the three teachers with little experience were less positive in general than the experienced teachers, their lack of positive attitude about the inquiry method was more an indication of their stage of development as a teacher.

> ....up until last year, was I used to say, okay we're going to do this experiment. Guys, here's the experiment, you know, you've got a picture of what the experiment looks like. Do this, this, this, and this is what we're going to do. And I'll say it, okay, before they write it up, here's the steps, I want method, I want you to do this... . And I'm thinking, no, why am I designing the experiment for them. Let's give them the purpose. This is what we want to see. This is what we want are trying to find out. And say, design the experiment. And they, the first time, they looked at me like I had asked them to explain quantum physics to them. They said, well, how do we do the experiment. I said, no, I'm asking you, how do we do the experiment. .... .Of course, its going to take longer than me just telling them how to do it. But it was better. It was their experiment. They designed it. And then they had no reluctance to bring it up to the front and show. Because it's look what we did. ....They weren't all the same. And neither were the conclusions. They didn't all answer the hypothesis the same way, ... (GN6)

> ... its hard to set up an inquiry model of things.... All kinds of logistical things, including lack of equipment, that make this whole outfit extremely hard to do. It's almost like somebody said, okay we're going to design this to cause the system to fail so that we can say there's a big problem in education. (HN6)

Technological Design:

Teachers' responses on how they are fostering the students' ability to construct the technological design method of learning are parallel to those given in the inquiry method and for the same teachers, except that the degree of change is to a lesser extent. As with the inquiry method, the majority of teachers are implementing the Technological Design method of learning.

> Two years ago was the first time I entered the competition at the college. The bridge building competition. ... Let's just make a bridge that doesn't fall apart when we pick it up. So we can use this much stuff, but we don't have to use it all, cause weight is also a consideration. And so that's design, and they designed it. ... The application was clear, structures and bridges. ...we (the teacher and students) have this, we talked when we had done our structures thing and we had talked about curves, shapes, if the triangle is the strongest shape that there is. We talked about all those things and of course we had a layout, it had to be a certain size, so we had some parameters we had to work within. And then we just basically went from there. (GN6)

> ....the technology and design, business, like there's parts of it you can do out of a book, there's parts of it that require the tools, and we don't have those. It's just not there. ...We have talked about when bridges collapse and why they collapse and why they build expansion joints into bridges, stuff like that. But I don't consider that, you know, exactly what they're meaning is in the new curriculum anyway. (HN6)

Questioning Skills:

The ability of the student to develop their own questioning skills is of paramount importance as it is a skill intertwined in the inquiry and technological design method of learning. All teachers that answered this probe say that they are developing the students' questioning skills as this helps students to learn how to learn. The teachers' see this as helping students to understand the material their own way and thus depending on the type of class, this can take a short or a long time. Teachers are doing this in a variety of ways: through the use of labs where students make connections by answering their own questions, to simply involving students more in asking questions, to integrating it across the curriculum so the student experiences it often, to teaching students how to ask questions to get the desired answers. A few teachers say that they have been doing this for years. The answers from the respondents were similar and were not related to experience or whether they were a science specialist.

> ... you have in some cases, have to go backwards and actually teach kids how to do this. If I back up and teach them, how do you take something and ask questions about it. And what you do is you start with a problem, ... and you say okay people, what three questions could you ask about that particular problem. Alright, what's wrong with these questions. How could they be reworded differently and actually you have to sometimes go and say to the kids, here's how you question something, here's how you have to actually question it. And again, depending upon the class you've got. So in some cases you don't have any problems, and in other cases, you might spend two or three weeks doing nothing but showing them how to take questions apart, which is also part of their English, so it's a crossover again.(IN6)

More/less classroom structure:

Three teachers say that there is less structure specifically with respect to labs and the inquiry method:within this group one teacher feels that there is more structure when teaching the concepts and another teacher feels that sometimes more structure is needed e.g. to problem solve. One other teacher says that although there is no change in structure that his style is to teach for about 10 minutes, leaving the remaining time for the students to do their tasks on their own or in groups. One teacher feels that there is more structure in his class, and that it is necessary to cover all the many expectations using his direct teaching style.

> I found that in my first couple of years, when you are teaching some things like science, I did structure the classroom a lot more till I got more familiar with how the students would

> cooperate. My classes are a little bit more open right now, basically, because I know what works and what doesn't work. ... So I think that would probably have to do with the experiments and comfort level of the teacher in how the classroom operates. (EY6)

In summary, the changes that have occurred in the means of instruction include a few broad changes with the majority of teachers allow learning to occur in small groups, developing the students' skills of scientific inquiry and technological design, developing the students' questioning skills, and less classroom structure specifically with respect to labs and the inquiry and design method when this is being done. Although some teachers are finding the construction of the inquiry and design method of learning overwhelming, or haven't implemented it yet, the majority see it as a positive change. The less experienced teachers were less positive about fostering the inquiry and design method in their classroom. This appears to be a reflection of their relative inexperience. The majority of teachers are also developing the students' questioning skills as this helps students to learn how to learn, and it is also a skill intertwined in the inquiry and technological design method of learning. This question thus partially answers the research questions on the changes teachers made to adapt to the new curriculum, and the challenges teachers faced and the solutions found in implementing the science curriculum.

Question #7 What changes have occurred in the methods of evaluation?

This interview question is aimed at addressing some of the issues relating to research questions 3: What changes have teachers had to make in order to adapt to the new curriculum? and, 4: What challenges has the new curriculum posed and what solutions have they found for these challenges? The changes can be categorized under (i) the development of rubrics (ii) self and peer evaluation and (iii) interpretive changes

Rubrics:

The majority (six) of the teachers use rubrics extensively as a tool in the evaluation process, with one teacher using rubrics sometimes, and one other teacher not using rubrics at all. The teachers using rubrics all felt that students are well aware of the distinction between levels, what a level 3 represents, and are constantly converting levels to percents. The use of rubrics was not related to experience or specialization.

I think students are becoming comfortable with the [use of rubrics], you know, how was I evaluated on this and having it broken down into different areas ... and in my classroom I have up on one of my bulletin boards above the board,.......it gives a list of criteria as to what would constitute a level one, what would be a level two, a level three, level four. And you talk to kids and when they get a level two on things, they'll say, yeah, I know, I didn't do enough on it. (CN5)

Although HN6 does not use rubrics, he has his own method of evaluating students:

I don't use rubrics as such. Like I don't pass out, like some teachers do, a rubric for every little assignment. I give them what I call, notes on notes, at the beginning of the year, which basically is a rubric for how you get through science, including how to study, how to do your notes, how to perform experiments, how to do diagrams, well the rubrics are all there. (HN6)

Self and Peer Evaluation:

The majority (six) of the teachers use self and peer evaluation in presentations, activities, and experiments to name a few. Two of these teachers feel that students tend to be subjective and not critical enough while the other four teachers feel that the inclusion of the student in the evaluation process is a good one - but the process must be explained to the student and the student needs to be accountable. The responses were unrelated to experience and specialization.

I think its good, I find the students are harder on themselves than I am on them. They are much more self critical, a lot of times. ... So I think it works, I think it helps, you can't just do it and not discuss it though. I mean, discuss it either as a class, in small groups, ... I'm concerned about somebody getting personal,....especially when I'm having a presentation, this group has to go up and present, I'll have these other groups evaluate them. .... Here's a group, okay guys, you're going to evaluate them, I'm going to evaluate them, and we'll discuss it later. ... And then I'll say remember, you get your turn up there too. So be fair, be honest, but don't be hurtful, don't be petty, I want an honest evaluation. And I want you to put them into a level, cause they understand levels ....(GN6)

There is definitely more emphasis on self evaluation and that's something that they really struggle with. I find that they are very quick to say oh its fine, everything's good, here it is, I'm done,.......it seems to be very difficult for them to do. Same as peer evaluation ... the group I have this year, many have been good friends for many years and they won't go out on a limb, to say, but I think this could be improved. ....I see them as being areas that the students need more work with, they need to be exposed to them more, and feel more comfortable. (CN5)

Interpretive Changes:

The majority (five) of the teachers use levels to evaluate students' work, and these 5 teachers are constantly converting levels to percents. The teachers discuss their concerns about the somewhat subjective and sometimes difficult task of assigning levels, as well as the various interpretations of converting levels to percents:

So, I think, the whole idea of the methods of evaluation, ... you level everything, and then what we do, is we have set marks, so if you're a level three, you get a seventy five on your report card. If you're a level two, it's a sixty five, if it's a level three minus, it's a seventy two, if it's a three plus, it's a seventy eight. And that's it, so there are only certain number that will show up on the report card ....it's the message that comes down, because some teachers get the message and some teachers don't get the message, or I get a different message than you do, so we're all doing our own thing and coming up with our marks and so my level three might be different than your level three. (CN5)

Three of the teachers feel that in-service in this area would be useful:

...I think there's still a lot of questions about evaluation. I think there's a need for p.d. There's a need for some instruction, some more workshops as to how do we standardize this, how do we make sure we are on the same level as everyone else. (CN5)

This question thus partially answers the research questions on the changes teachers made to adapt to the new curriculum, and the challenges teachers faced and the solutions found in implementing the science curriculum.

One teacher feels that one of the changes that occurred in the evaluation process is the decreased accountability on the students' part as a teacher has to give the students many opportunities to submit late work. Another teacher feels that one of the changes that has occurred is that the various methods of evaluation are not considering the process, only the product. At this point, the responses appear to be unrelated to experience and specialization.

In summary, the majority (six) teachers use rubrics and self and peer evaluation extensively and this appears to be unrelated to experience and specialization.

Question #8 What do you know about the implementation process for the new curriculum?

This interview question is aimed at addressing some of the issues relating to research question 1: What knowledge do teachers have of the implementation process?

The major issues that were discussed included: (i) the time frame (ii) what has been done in the past (iii) what is going to be done in the future

Time frame:

All teachers believed that the implementation of the science and technology curriculum was scheduled for two to three years, and the majority felt that they were maintaining the schedule set out by the board. The majority of the teachers plan to implement in three years, covering two strands in year one, two additional strands in year two, and the fifth strand in year three. One experienced teacher feels that three years is unrealistic. Two of the experienced teachers plan to implement in two years using a three, two split and these two teachers have allocated the most time to teaching science.

> ...I know that our Board has implemented two strands this year, with the life science and the energy and control. Next year they are implementing another two strands, and in the following year they are implementing the last strand. So there is going to be gaps. There is going to be students that just don't get all five strands until that third year, But basically you are just going to fill in as much as you can for them. (AY5)

> For our Board the time frame I believe was, we were to have implemented the five strands by this year. We only had to do three in the first year. I haven't paid a lot of attention to it, because like I said, we've done all five any way so it really hasn't been an issue. And so where's the implementation process at the present time. It's done. It's implemented..(FN6)

What has been done in the past?

To relieve some of the burdens and difficulties associated with the implementation of the new curriculum, the Northern Ontario Catholic Curriculum and the Central Ontario Catholic Cooperative collaborated on the development of curriculum resource packages for teachers to support and provide tentative help in the implementation of the science and technology curriculum. All teachers but one had received some resources, and textbooks in the past. The majority of the teachers were either not sure what was done in the past, or did not recall. Two teachers felt that they had little say or control over the curriculum that was given to them. Teachers discussed receiving grant money for texts and lab equipment.

> We have something from OECTA, which is the Catholic curriculum. Our board has purchased those and I have some of that. I think I got life systems and energy and control. (BY5)

> Never paid any attention to it or very little....Saw stuff in the paper and all that kind of thing. There wasn't anything that I was particularly interested in. We knew it was coming down the pipe. We knew we had very little control about what was happening. We knew it was coming from Toronto, whatever they decided.(FN6)

What is going to be done in the future?

The teachers are all committed to implementing the curriculum, some in two years, the majority in three years, with two teachers of the opinion that integration with other curriculum is also necessary. All teachers felt that support was needed. Their expectations included more in-service, workshops, professional development, teacher resources, equipment, and textbooks. Most teachers were unsure about what their board's future plans was for the implementation of the science and technology curriculum.

> So I think its going to take more scheduling on my part to try to get all of that in. It's going to be hard to fit five into a year. I think its going to be very difficult and I think we have to keep looking for better way of integrating it into other curriculum.(CN5)

> I see all these Board people smiling and talking about their wonderful curriculum. On a certain level they are right, but what's the next step. What are you going to do to prepare us properly for the new curriculum. And do it well. They want good results. Then they have to be prepared to put the effort into it and I just don't see that happening. (DY6)

In summary, when teachers were asked what they knew about the implementation of the new curriculum, their discussion included the time frame for the implementation process, what they knew of that was done in the past, and what is going to be done in the future. All teachers believed that the implementation process was scheduled by the board for two to three years, and the majority of teachers plan to do so in three years. In the past, all but one teacher had received resources packages and textbooks. The resource packages were developed for teachers to support and provide tentative help in the implementation of the science and technology curriculum. Teachers also received grant money for texts and lab equipment. Most teachers were unsure about their board's future plans, but their expectations for the future include more in-service, workshops, professional development, teacher resources, equipment, and textbooks. This question thus partially answers the research question on teachers' knowledge of the implementation process.

4.2.B Interview Two

Data is presented in this section for questions one to eleven. The common trends, patterns and elements that the teachers express are discussed using direct quotes. Since nine teachers participated in the interviews, the term "majority" will continue to be used to indicate that five or more express a similar opinion or view.

Question #1 What professional development activities have been planned (short/long term

training) to assist in the implementation of the science and technology curriculum?

This interview question is aimed at addressing some of the issues relating to research question 1: What knowledge do teachers have of the implementation process?

The three categories found in the answers to this question are (i) short term training (ii) long term training (iii) Professional Development replacement

Short Term Training:

This question was answered in part in question 2, interview 1 under the theme Professional Development (PD)/In-servicing, where it was found that the PD experienced by teachers included one to three workshops organized by the board, OECTA, or by Nelson and ranged from one half to one day in duration. It was also found that the majority of teachers feel that more professional development is needed. However, during this interview, a few specific details about what teachers have experienced as professional development is brought to light, namely that of one-half day workshops for specific strands or units and workshops on the inquiry method.

> This past year we had a half day session, right near the beginning, in September, the first PD day that we had, we had a half day session with all the intermediate science teachers. And they tried to introduce a little bit of the curriculum (for) the two strands that we were doing. ... There was also another half day workshop which was in the second term and I can't even remember the month that it was in. ... So that's what we had this year in terms of it. I'm not sure what they are planning for next year, though I am sure with some of those P.D. days that we have, there's one again the fall, that they will probably have a workshop with some sort with the new strands coming in, but I haven't heard anything definite. ...In the summer the government is offering the hands-on minds-on science. They are offering free four day workshops and one of them is a science. ... its based on the curriculum and different approaches that you can put directly into your classroom, different activities. ... And they're free. They are being offered through the unions and its actually joint, the unions and the government. (AY5)

Long Term Training:

All teachers did not know of any on-going professional development planned for the future that was to be put in place to continually assist teachers in the implementation of the science and technology curriculum.

> At present, I am not familiar with anything that is planned. Last year there were some workshops held for one of the units in the grade eight curriculum but I am not aware of anything that is planned for the immediate or long term. (EY6)

Professional Development Replacement:

To replace the severely lacking professional development required by teachers, the majority of teachers are utilizing the resources from the Board, OECTA, their colleagues, and the textbook teacher resources form the publishers.

> There is also a binder that has been put out by the Board, using the curriculum as a base for some more hands on activities. ...Oh there will be more inservice training, ...there is so much on the go, I think they are trying to fit it in as the problem occur, more than anything else. ...A lot of it is, deals with how do you take the concept and get it to hands on. Because basically at this age level, especially at this age level, the more praticum you can have, the more meaning it has. (IN6)

> I haven't done any this year, and in checking what has come out for January and February there isn't any for intermediate science and that, and that area. The only one that I have been to is the publishers workshop for Nelson. (BY5)

In summary, the majority of teachers have had one to three workshops of either one-half to one day duration on specific units or strands and/or the inquiry method organized by the board, OECTA, or by the textbook publisher. None of the teachers were aware of any on-going PD planned for the future. This question thus partially answers the research question on teachers' knowledge of the implementation process.

Question #2 What feedback have you received from parents about the present science and technology curriculum?

This interview question is aimed at addressing some of the issues relating to research question 4: What challenges has the new curriculum posed and what solutions have they found for these challenges?

The categories for this question are (i) positive feedback (ii) negative feedback and (iii) why little to no feedback. It is noted that there was very little feedback from parents although there were a few positive and negative comments.

Positive Feedback:

Five teachers received positive feedback, but from only a few parents. These teachers discuss that parents feel that science is important and challenging, and are impressed with the continuity and hands-on nature of the program.

> ...a lot of parents, I think, seem to like the fact, they seem to like the fact that there is at least some emphasis on science, or there was, or appears to be some emphasis on science. I know they like the hands on things that I do. I don't know if that's across the board but my own feedback has been that they like the fact that their kids seem to enjoy doing science experiments and those sorts of things. I haven't heard of any great criticism about the new curriculum. ...School council, and parents, they've had access to what the new curriculum is. ... So I don't think there's a real problem with it at all. I think they like it. (GN6)

> ...we've had some feedback in terms of the curriculum document which we have a set of these downstairs. We have a parent association notice board. There is a set down there for parents to take home and read. Parents like the continuity. They like the fact that it is arranged in strands and that from grade 1 to 8 there is a continuum and they can see that. And they like that. I think they like the fact that kids right across the province and right across our board, are doing the same thing in terms of the curriculum,... (FN6)

Negative Feedback:

Three teachers received some negative feedback, but only from a few parents. Two of these teachers had also received positive feedback from a few parents. The teachers discuss parents' concerns about the material being advanced in nature for the grade 8 curriculum, and about the lack of materials needed by the students to complete their activities.

> ...with the way the Nelson is set up in some of the science, a lot of it is take home stuff to build and do, not just at school, and they were concerned about materials and that the school wasn't providing - just things to build with, ... That's about all I've received from my parent point of feedback. (BY5)

> I haven't received a lot, ...but at the same time a little bit of questioning, is this too much, is it too advanced, they're only in grade eight, so its both a concern and a kind of being impressed, hey look at what my kid is learning. (CN5)

Why little to no feedback?

All teachers received little to no feedback from parents. Teachers feel the reasons include: parents have access to information that is sent home through newsletters, memos, course outlines, the curriculum document, and school council. The curriculum document is also readily available at the school. Four teachers discuss their sessions with parents explaining the curriculum to them.

> I haven't heard any negative comments regarding the curriculum we are doing. I think a lot depends on the individuals presenting it, specifically the teachers in the school, how comfortable they are with it, and how well they are able to communicate what's in the objectives and the guidelines, and like I say, I am in contact with parents quite frequently and I honestly can't recall any comments regarding the level of difficulty. (EY6)

> ...we sent home information pages and the information pages for example, included all of that information. ...and this was something that was done at the school level, so we made very sure that our parents were very well aware of what the document had to say. What

> the strands were. That they are familiar with levels. That we were looking at what the expectations would be. That sort of stuff. ... So if they [parents] have a question you can open the document and say, well this is why we're doing it and here it is. And you can see the expectation in black and white. (FN6)

In summary, although there was very little feedback from parents, it was both positive and negative feedback. The positive feedback was received from only a few parents. These parents feel that science is important and challenging, and are impressed with the continuity and hands-on nature of the program. Negative feedback was also received from only a few parents. The parents are concerned about the material being advanced in nature for the Grade 8 curriculum, and about the lack of materials needed by students to complete their activities. Teachers feel that there was little feedback from parents because the parents are already informed about the curriculum through newsletters, memos, the curriculum document, and the school council to name a few. The responses to this question were unrelated to experience and specialization. This question thus partially answers the research question on the challenges teachers faced and the solutions found in implementing the curriculum.

Question #3 What are the main concerns of other teachers in the school with respect to the implementation of the science and technology curriculum?

This question is not included in the final analysis of the four research questions as this question is not based on the perceptions of the teachers in this study but is instead based on the perceptions of the other teachers in the school. This question is included to compare the challenges faced by these two groups of teachers.

The major concerns include insufficient: knowledge, time, resources and inservice

Knowledge:

The majority of teachers feel very strongly that teachers with little experience (new) or teachers with little to no science background are not comfortable teaching science because of their lack of base knowledge. Teachers discuss the concerns of others not being comfortable teaching the new curriculum with new terminology, answering complex questions as well as teaching using the inquiry design method. Teachers are concerned that depending on the teacher's expertise, the student can be inadequately prepared for the science curriculum in the future.

> Well, I think some of the concerns is that there is no specialist training for teachers, for elementary teachers, for science, and some of them have expressed, I don't know if I would call it a fear of the content, but a, you know, an apprehension, of their knowledge of the content that's required. ... None of them that I know of, or very few anyway, elementary teachers they have a specialist in geography or history or science....(HN6)

> Because some of the terminology and some of the concepts if you weren't a science major, you don't have a great understanding of it. To go with that, my student teacher, ... she said what do I do if they ask me one of those what if questions, and I don't have enough background to say well this is what would happen, because she doesn't have a great grasp of some of the important concepts, not the important, but the complex concepts. ...some teachers are concerned because they don't have that comfort level to answer those kinds of questions. (BY5)

Time:

Four teachers discuss teachers' concerns about not being able to cover all five strands of the curriculum and do it well.

> ...and the comment is often made ... do you ever feel like you did a really good job teaching that strand of whatever it is. And generally the consensus is no,... This is as much as I can do in this time and you walk away feeling that well I really didn't do the best job that I could have done. And I hear that a lot, I mean, I've expressed that to other teachers here and I've heard that from them and they said, you just have to live with it. Get as much done as you possibly can and then, you have to move on. (CN5)

Inservice/Resources:

The majority of the teachers feel that the other teachers feel that there is a great need for inservice.. Inservice was seen as an opportunity to obtain new ideas and direction. The majority of the teachers also feel that there is a great need for resources. These teachers feel that the resources needed include textbooks, lab materials, lab space, equipment and hands on materials. Two teachers discuss the need for a science lab.

> Yes, but basically the feeling that I'm getting, and its strictly a feeling, is that other teachers are waiting for more, they are waiting for more inservicing, maybe a little more direction. It would be nice if the government could do the same thing as they are doing with the language program in providing samplers.(DY6)

> I would assume if I have the same concerns, I would assume that it covers most other people. Cause space in here with different things, like when I do the fluids unit, there's quite a bit of material required for it, and they can get a room very crowded and time wise as well, its hard to clean up from one and get another one started for a different grade with different materials. (BY5)

In summary, the majority of teachers interviewed feel that inexperienced teachers or teachers with little or no science background have the most concerns. The teachers interviewed felt that the other teachers question themselves about: whether their knowledge base is sufficient, their inadequate knowledge of new terminology, their need for acquiring the skills of thinking, inquiry, and problem solving, and the vast scope of the curriculum. This subsequently leads to teacher concerns about whether there is sufficient time to implement the curriculum, and the feeling by the teachers for a need for inservice to assuage these problems. The majority of the teachers see a need for more resources in order for the science and technology curriculum to be successfully implemented.

Question #4 What are your main concerns about the implementation of the science and technology curriculum?

This interview question is aimed at addressing some of the issues relating to research question 4: What challenges has the new curriculum posed and what solutions have they found for these challenges?

The major concerns include insufficient time to cover the curriculum, and the need for resources.

Extensive Curriculum:

The majority of the teachers feel that the curriculum is extensive and their concerns revolve around how to address the expectations within 10 months of instructional time. The majority of the teachers feel that to cover all five strands of this comprehensive curriculum, they need to integrate the curriculum and are doing so, but question whether the students are adequately prepared for the next grade. With the exception of one experienced, non-specialist who had no concerns, and one inexperienced specialist who made no comment, all of the remaining teachers felt that there was inadequate time to implement the curriculum. Therefore the responses to this question were found to be unrelated to experience and specializaton.

> I mean, there are a lot of expectations in all of the curriculum. And its difficult to cover. ... What you do is you learn to combine things, to meet outcomes - to combine activities that maybe demonstrate more than the one thing. ...Integrate within the strand. And also between strands. I mean, there's no reason I can't integrate language, math, and you know, art perhaps, depending on what the activity is, with science. ... because you can't break everything out into each little expectation and expect you're going to have time to cover them. It's not going to happen.(GN6)

> As far as having enough time for science in a week, yeah, but as far as having enough time to do all five strands, and do them all extremely well, no. So you'll do three really well, you'll do one fairly well, and you'll touch on one. (IN6)

Resources/Inservice:

The majority of teachers discuss their need for textbooks, equipment and space for a science lab, and two teachers for inservice support. The majority of teachers feel that having the hands-on resources is crucial in science for the development of the student. The responses to this question were found to be unrelated to experience and specialization.

You can't have nine kids around one little thing doing one experiment. I mean you have to have them in smaller groups which means more equipment. And I think it will come. I hope it will come quickly. ...There's not, there's a lot of cutting back going in certain areas, and hopefully, the commitment will be made to this and the money will be there to buy stuff. ...we have to have it, and if we complain loud enough , hopefully then someone will find the money. (GN6)

As far as I'm concerned we are still at the phase where we've been given all these documents, and yet we're waiting to get a little bit more. ...I'm not expecting to be told how to teach the curriculum, but a little bit of inservicing in terms of how we can address the expectations in skills and knowledge, maybe some inservicing on integration, on how maybe we can cover two at once, cover skill and a concept. That would help. (DY6)

If you had a science room, then you could make it look, you could show off your things that you have and the different activities that would be available to kids. When you have a classroom where you're teaching every subject and I mean, I have microscopes on a trolley back there, but, I can't always keep them always in my room or I can't leave them out because we have everything else going on. You've got to push things aside and make way for the history project or you know, visual arts, I mean we do everything in here, so that's harder to do I think in an elementary school where they don't have specific subjects set up. ...And space. I mean, I have twenty nine kids, I started out with thirty two in here, and we're bumping into each other, there's not enough room. ...It's gets pretty hard to do and I mean these are grade eight kids, they're not little. So, um, yeah, we have, we try our best, but there are certainly some limitations. (CN5)

In summary, the majority of teachers feel that in order to cover the entire curriculum, they need to integrate the curriculum, as there is insufficient time to do it all and do it well. A few teachers feel that more inservice is required in order to prepare teachers for the new curriculum. The majority of teachers feel there is a need for more textbooks, equipment and space for a science lab. None of the responses seem to be related to experience and specialization. This question thus partially answers the research question on the challenges teachers faced and the solutions found in implementing the curriculum.

Question #5 What could the school board do to enhance the implementation process?

This interview question is aimed at addressing some of the issues relating to research question 4: What challenges has the new curriculum posed and what solutions have they found for these challenges?

The majority of teachers feel that the board could provide more resources and professional development to assist in the implementation of the science and technology curriculum.

Resources:

The majority of the teachers feel that the board could provide more resources with respect to equipment and materials for science labs, textbooks, and supplementary textbook resources, materials for lesson/unit planning, and for assessment/evaluation, and a science lab.

> As far as how the money works, having the books for the kids would be helpful as well. ...but the materials and things for the lessons, those kinds of things just a basis to work from, where I'm not reinventing the wheel. Every unit I have to think of a magical way to piece it together for seven weeks. ...I would trade textbooks for materials and a science room. I would take a science room ... ...over textbooks I am sure, cause that way I can use that room to teach from my master textbook, if I had the choice. In the ideal world, I'd have all three. You could do the science, in a science room with equipment, without the book. (BY5)

> I haven't felt like they have approached us and said what are your concerns about the curriculum, you've been doing it now for a bit, you've partially implemented it. What do you think you need. And if they can find that out from us ...then they can take it from there, that would be great. I haven't seen any of that though. (DY6)

Professional Development:

The majority of teachers feel that the board could provide more professional development. Teachers see a need for more inservice training in areas on how to teach the curriculum, when and how to connect similar concepts and do so efficiently in a split grade classroom, and how to develop in the student the skills of inquiry and design. Teachers are asking for workshops on specific units.

> ...they could just sponsor and just support even board level inservicing. ...I would just like to see their curriculum people spend a little, maybe plan, a little more indepth inservicing. ... kind of get ideas on how we can go about teaching this new curriculum without it being just the delivery of concepts and the delivery of information. Because really its information loaded curriculum as far as I'm concerned and there has to be different methods of getting that across to young kids ... I think one of the things for me, personally, would be the inquiring design skills, How can I get kids to learn the curriculum through their own initiative or their own ability to solve problems. (DY6)

> They could provide real training courses for the teachers that aren't an hour or an hour and a half after school, when you're burned out from dealing with thirty one kids in your average twenty five class. A real training program for me for implementation of this, would require, you know, a whole day, maybe once every two or three weeks, for a year, to train us how to actually do some of this stuff, maybe even train us on content. It may be part of a Faculty of Ed deal, but they're going to have to send us there, not during the summer, not after school either. It's going to cost money. (HN6)

> I would like to see professional development set up more for giving us that knowledge base, and the ideas, the strategies to use in order to teach the curriculum. ... the question that comes up for a lot of teachers is if I have a split grade, then how can I make those connections between let's say the grade four and the grade five science, because ultimately there may be some things that are similar and, you know, ... So teachers are always looking at ways of how can I teach a split grade more efficiently and split grades are a reality... (CN5)

Only one teacher feels that the board is currently "trying to do their best with what they've got" (IN6) in the implementation of the science and technology curriculum.

In summary, the majority of the teachers feel that the board could provide the funds to supply equipment and materials for a science lab as well as teacher and student textbook related resources. The majority of teachers feel that there is a great need for teacher training and development in the effective use of the curriculum document in the science and technology area, specifically with respect to teaching science concepts effectively in a regular or split grade classroom and the development of the skills of inquiry and design. The responses to this question did not seem to be related to experience and specialization. This question thus partially answers the research question on the challenges teachers faced and the solutions found in implementing the curriculum.

Question #6 What could the principal do to enhance the implementation process?

This interview question is aimed at addressing some of the issues relating to research question 4: What challenges has the new curriculum posed and what solutions have they found for these challenges?

The categories found in the answer to this question included more resources, increased communication, and more inservice/professional development.

Provide Resources:

With the exception of one teacher who made no comment, the majority of the teachers feel that to enhance the implementation process, the principal could provide the needed money or resources.

> Pushing for, I mean they have to advocate for their school and for their staff that we need these things and could somebody please figure out a way to pay for it. I mean, I think that's what's best. (GN6)

Two teachers discuss what was done in the past as well as what is being done now. A typical response of what was done in the past includes:

> He is really supportive. ...If I go to him and say, is it all right if we do that, he says, what are you asking me for. So he is very supportive that way. Secondly, if I need materials, paper materials or whatever, and I go to him, if it's a significant expenditure, he will say, what you should do is talk to your colleagues in the division to make sure you know how much money is in the budget you have to buy materials. Just make sure that they are comfortable with what you are spending. If they are comfortable, do it. If I want to go to a workshop, or something of that nature and there is no coverage provided by the Board, he'll say, go, I'll take your class. (FN6)

Increase Communication:

Two teachers discuss the principal's role in ensuring that there is communication between the school and parents, and between schools.

> The one thing that I thought and ours did a pretty good job, maybe is helping to keep the communication open between schools so that if you needed to borrow materials or something along those lines, it was much easier to do, that's one thing that we did with other schools, is sharing equipment once in awhile if you weren't using it and they needed and we would go back and forth. (AY5)

> Perhaps if at the beginning of the school, the opportunity was provided for the parents to know what was required at that level of assignments. Just to familiarize them with the type of material and the amount of material that's required. Communication is important and I think that would be an important role for the principal to take care of. (EY6)

Provide more Inservice:

Four of the teachers feel that the principal could provide more inservice or professional development.

> ...right after that half day we had, all three of us walked into there just to let him know we thought it was a completely useless morning. That how can you have such revolutionary changes in the science curriculum and then give your science teacher a half day. (DY6)

Our principal right now is wonderful. She is curriculum based and if you need something in order to teach a subject, she will get it. ...principals can look at even if there's not professional development happening at a board level, principals can bring people in to do professional development at a school level. We have the days, we only have two P.A. days in the year, throughout the year, and they're supposed to be for reporting to parents, ...and I know there's, there are so many other issues that the principal want to bring forth for P.D.,but those would be times that there would be a possibility of doing something science based. (CN5)

Positives/Negatives:

The majority of the teachers feel that the principal is doing a good job, is an advocate for the school and the staff, and is very supportive.

I think my principal is pretty supportive of us, encourages us to try, to try new things, to take risks, not safety risks, but risks in trying new things, unknown things that may not work for us, you know, when you try a new lesson it may blow up, it may not work, it may fall flat. But she's really encouraging, go ahead try it, you know, why not, it may turn out to be great. So other than that, its like pushing for money. (GN6)

Two teachers discuss what the principal is able to do as opposed to what the principal can do as the superintendent or board makes the decisions about what and how things are done.

Well basically his hands are tied with what the monies are. And what the board says. I mean if you've got a good principal and he can, I think you use the word juggle the figures, but sometimes he'll find some extra, sometimes they even take it out of say petty cash funds, but basically their hands are tied with what the board tells them they have available. (IN6)

In summary, the majority of the teachers feel that the principal is doing a good job, or as good a job as he/she can and that the majority feel that the principal could enhance the implementation process by providing more resources. Inservice/PD was seen as a need by four teachers. The responses to this question were unrelated to experience and specialization. This question thus partially answers the research question on the challenges teachers faced and the solutions found in implementing the curriculum.

Question #7 What do you see as your role in the implementation of the science and technology curriculum?

This interview question is aimed at addressing some of the issues relating to research question 4: What challenges has the new curriculum posed and what solutions have they found for these challenges?

The teachers' roles in the implementation of the science and technology curriculum include: (i) knowledge and understanding of the curriculum and (ii) delivery of the curriculum from teacher to student.

Knowledge and Understanding of the Curriculum:

The majority of the teachers discuss one of their major roles in the implementation of the science and technology curriculum is ensuring that they are prepared to teach the curriculum. Teachers discuss the developing of their knowledge base in order to increase their understanding of the curriculum. The responses to this question were unrelated to experience and specialization.

> My role is to be very aware of what the curriculum is and what the goals of it are so that I can carry it out with my students to the best of my ability and make it very clear. Be able to keep in contact with other teachers so that we can share our ideas and our understandings, and even at these workshops you can tell when we discuss, they did just a few little activities with us to use, and even the way we interpreted what was being asked of us or ..... the curriculum even the way we interpreted was very different. Just being able to make sure that I am keeping the lines of communication open . (AY5)

> ...I don't have a science degree, but I think if you do your professional development properly and if you take, when the opportunity presents, do workshops with people who

are expert and can show you, or walk you through the steps, and then do some darn hard work yourself, to make sure that you are prepared, make sure that you know more than the kids do, and then just practice it. ... it has a great deal with having to do with working with the science programs for years. ...You do your homework and it just isn't that tough. ...Make sure you understand the material that you're doing. (FN6)

Delivery of the Curriculum:

The majority of the teachers feel that their second major role in the implementation of the science and technology curriculum is delivering the curriculum. Teachers discuss the teacher-student interactions involved in the delivery of the curriculum. Teachers see this role as (1) finding different ways/strategies to pass the information along to the students in order for them to understand the curriculum and make connections (2) challenging the students to foster problem solving, to explore and inquire and to develop critical thinking skills, and (3) to guide students to become independent thinkers and learners. The responses to this question were unrelated to experience and specialization.

> ...find ways to I guess, ways to pass it along to the students, that make sense and make connections to them. ...because the grade eight curriculum is pretty abstract and its pretty in-depth, there's some pretty heavy concepts in there that I need to find ways to, not water down, ...to make it a little more understandable and then to have them build up to the actual understanding of it, to find ways to make connections to the very, the actual thought they should be understanding of the concept. (BY5)

> I don't want to lecture at them and tell them this is how this is and this is how this is, and make all these notes. That's not my role. ...I think in science my role is just to guide them along as they try to explore, to explore. To inquire, to find answers. You know. I think that's my best role. Just to lead them, keep them safe, keep them interested, keep them going in the right direction. ... Hopefully, more and more and more and more, is I'll present them with a problem and they'll jump in together to find, how to design the solution. You know, that would be great. And it happens sometimes. ...You know they take some ownership for their ideas. And their ideas, they carry weight and they have

merit, because they came up with it, they didn't just take some direction from me. (GN6)

One teacher sees one of her roles as explaining the what and why of the curriculum to parents.

> And also to, my role is also dealing with parents and explaining to them what we are doing and why we are doing this when they never took it in class, they never took it in school. (CN5)

One teacher sees one of her roles as maintaining contact with the other teachers. This is an inexperienced teacher who is a science specialist.

> ...Be able to keep in contact with other teachers so that we can share our ideas and our understandings, and even at these workshops you can tell when we discuss,... the curriculum even the way we interpreted was very different. Just being able to make sure that I am keeping the lines of communication open . (AY5)

In summary, the majority of the teachers discuss their roles as developing an in-depth knowledge and understanding of the curriculum in order to deliver the curriculum. Teachers discuss the delivery of the curriculum to students in order for the students (a) to understand the curriculum, and make connections (b) to challenge the students to foster problem solving and critical thinking skills, and (c) to assist students to become independent thinkers and learners. The responses to this question were unrelated to experience and specialization. This question thus partially answers the research question on the challenges teachers faced and the solutions found in implementing the curriculum.

Question #8 What is your opinion concerning the use of achievement levels in your methods of assessment?

This interview question is aimed at addressing some of the issues relating to research questions 3: What changes have teachers had to make in order to adapt to the new curriculum? and 4: What challenges has the new curriculum posed and what solutions have they found for these challenges?

Six teachers had both positive and negative comments about the use of achievement levels. The remaining teachers had only a few comments on this issue, and they were either positive or negative. Thus there did not appear to be any correlation between their responses and their experience and specialization.

Negatives:

Teachers' question (1) the recording of percent not a level on the report card (2) the subjective nature of using levels and (3) the unrealistic attainment of a level 3 or higher by most students. Five teachers discuss the contradictory nature of assessing/evaluating using levels, but recording as a percent on the report card. Teachers feel that a level should be recorded if levels are used to assess/evaluate students' work.

> If I'm going to report in percentages, it seems kind of goofy to evaluate in a level and then during this magical formula, convert it to a percentage, because I might do it different that you would do it , than someone else would do it. (BY5)

> But I think that whoever is in charge of the evaluation will have to say, okay we are going to evaluate and this will be on the report cards, level one to four. You can't say that we are using this achievement level and then still expect marks from zero to one hundred. It's sort of contradictory. (EY6)

Three teachers discuss the subjective nature of levels assigned to students' work, as there is no consistent criteria used by all. Teachers feel that a less subjective mark or more fair method of assessment should be used.

> I try and not even look at the names when I am evaluating many things so that does not become a factor, but someone who usually does level three work, but maybe they didn't do very well on this assignment, and it's a level two, are you more likely to give them a two plus because, you know, or maybe up it a little bit, or a three minus. ... And we don't want to go back to just regurgitating information and assessing only on that. So, I have

mixed feelings about it, I really do, I just, there's pros and cons to it. But I think, I think we have a lot of work at getting better at using levels and understanding what they mean and just being consistent with what they are. (CN5)

One teacher discusses the use of achievement levels as a sterile method of assessment/evaluation.

...it's fairly objective because I'm simply commenting on their ability to, on their grasp of what I've taught. It's purely on what they know and what they've been able to demonstrate. ...The curriculum evaluation is purely outcome driven, and I found it rather easy. The only problem I think though is that it tends to make evaluation or the assessment sound kind of sterile and clinical. (DY6)

Two teachers feel that it is unrealistic to expect that most students will attain a level three or higher.

...the government says everybody should be level three. I'd also like to know how they came up with that. ...How they determined the average person should be level three, but anyway, the top end of level three, level four, might be good for the top ten percent of any kids I've had in this school anyway. And that expectation is way too high for the rest of the kids. (HN6)

Positives:

Teachers' discussion about the positive aspects of the use of achievement levels in their methods of assessment include: (1) uses levels most if not all of the time (2) Levels are clearly defined (3) the use of levels or percent has little effect on the final mark recorded as a percent.

The majority of teachers use levels most of the time and discuss their ease of use.

...in actually some ways, it as you become more familiar with it, you can assess things a lot quicker, you can almost scan something and in a couple of minutes and you can decide what level its at. So maybe to some degree its not too bad. (EY6)

Three teachers discuss that levels are clearly defined and this makes it easy to discuss the expectations for each level with the students.

> In some ways its easier as in doing the assessments knowing that its going to fall into four categories, its either going to be you know the level one, the level two, the level three or the level four. ...I like it in some ways... I could evaluate four projects at a level two, they could be very different and I'm picking different things out. If I'm using a rubrick, someone may have scored very high on one level but very low on another level and the other person's could be the total opposite. You know, but they all end up in that level two. (CN5)

Two teachers discuss the converting of levels to percent. They feel that within each unit whether levels or percent is used throughout the semester, at the end of the semester after examining all the levels or precents, there is little difference in the final mark that is recorded on the report card as a percent.

> It comes with practice and basically when you look at if you've got enough of your, I hate to call them, but I guess you call them test papers, ones that are out of a certain mark. If you've got enough of those, then you'll find that when you do your levels, that it doesn't have a great effect as far as marks are concerned. (IN6)

Probe: In what ways have you used the achievement levels in assessing the knowledge and skills expectations of the science and technology curriculum?

Teachers discuss: (1) the use of rubrics (2) the use of 3 different sub-levels (and percent ranges) within each level (3) the use of the entire percent range for each level and (4) the use of percent in tests and quizzes not levels. All teachers use rubrics for marking. Five teachers evaluate using sub-levels while four evaluate using levels 1 - 4 only. Four teachers evaluate tests and quizzes using percent only.

The Use of Rubrics:

The majority of teachers discuss the use of rubrics in their methods of assessments using levels. Rubrics are used extensively in labs, assignments, projects and presentations.

> I thought they worked well including the rubrics because they gave you quite definite word s that you could use for each level. Like a level three was often or sometimes did this or did that, so you could, it made it very definite when you were making a rubrics to assess your students. ...I would try for certain ones and then the levels made it easy to do that because you were very clear cut on what you were expecting .....It's sort of a roundabout process because you're using achievement levels to get their marks and yes, ... and when you're making up your rubrics, your using achievement levels, but your giving them a mark based on their achievement levels. (AY5)

> I like the rubric, the only thing is, developing rubric, because I know the expectation ideally is to have a rubric made for everything, and have it made before you even give the assignment and you know, when you work with a curriculum for a little while, eventually I think you are able to do that more, but when it's your first year teaching in a certain curriculum, I don't have all of those rubrics made. ...But I don't do a rubric for everything, there's no possible way that I'm going to develop a rubric for everything. ...You look at this rubric. I don't know. I'm not completely comfortable with them, ...there is a teacher who has been on staff here a shorter period of time than I have, ...and her comment was, well haven't you been sent to rubric writing workshops, and I said, no I have never been sent to a rubric writing workshop. So some teachers have had more instruction in how to create rubrics and others haven't and I think a comment that we've made is that, in our own school, is people have to be getting the same information and the same instruction as to how to use these assessment tools. (CN5)

The Use of Sub-levels Within a Level:

The majority of teachers are currently using three different percent ranges within each level as they believe this decreases the subjective nature of using levels. Teachers explain the differences between the various levels of assessment (levels 1 to 4), and their method used to obtain a level and subsequently a mark in the end. This is also explained with examples to the student at the start of term. Teachers discuss using the most consistent level within a unit, and converting that level to a percent, and this is already predetermined at the start of the semester.

> I have a problem with that. I mean, if I give a kid a level three, that's supposed to be what, seventy-five. It's half way between seventy and eighty, it's a three, so, does every single kid whose work is mostly level three get a seventy-five. Where is the guideline there. The government says its more accurate. And I'm saying, explain that to me, there's a ten point spread in there. So I give marks, three minus, three, three plus, and I try, and at the end I have to sit there, and I have to give a subjective mark. ...I don't have the answer for that. I try to be as fair as I can, that's all I can say. (GN6) .

> Because you're doing all this leveling stuff and then... you've got apply a percentage to it. So that's why I've got to a level with a plus and a minus to give me three different ranges to work in, and then to give percentage depending upon... Like you might have got a level three plus and over the year you did a lot of extra work and you made the attempt so I might give you a 79, as opposed to giving you a 76, or 77. (BY5)

The Use of Levels 1 to 4:

Four teachers are not sub-dividing each level and are simply using levels 1 to 4 where level 4 is equated to 80-100%, level 3 to 70-79, and so on. The teacher assigns a level 1, 2, 3, or 4 to a students' work, records it as a level, and at the end of each unit, determines the most consistent level. One teacher describes the process as relating levels 1, 2,3 and 4 to letter grades D, C, B, and A.

> It may come down to the point where I'll start recording marks as either being level one, two, three or four. And then when I evaluate that at the end of the term, I'm basically going to be looking for which one is repeating itself the most and I don't even know if calculation will be necessary any more. (DY6)

> I've actually geared a lot of my assessment to that. For example, a lot of the assignments are marked out of four or out of eight, you know multiples of four, and so I do have that

> one to four scheme in my mind for a lot of the stuff that I evaluate. ...Yes, you almost have to look at it as a letter grade as well, A, B, C, and D... relate it to the one, two, three and four. (EY6)

The Use of Percents:

Four teachers use percent in quizzes and tests, which are then converted to levels, and then to percents for the report card. Thus for tests and quizzes, a specific range in percent is associated with a specific level.

> Well even when I do some tests, some tests will end up as a percentage grade, just to make that ... and then they get their percentage grade and they will convert that to a level, so the test might be out of a hundred and they get perfect, but its only a level two type test,... . Like if I give you a quiz, I prefer to mark it as a percentage. You get six out of six, you get a 100. But if you do a project for me, if you design something, well, that's a level three because you've met these expectations, so I think hands on things lend themselves more towards levels, like I level my art, my phy. Ed. I level my activities, but when it comes down to actual pushing the pencil kind of thing, I don't know, I find the differentiation is hard to make cause I know at some point I have to get a percentage. (BY5)

In summary, teachers' opinions concerning the use of achievement levels in their methods of assessment are divided. The majority of teachers have both positive and negative opinions about the use of achievement levels. On the negative side teachers question the contradictory method of assessing using levels, but recording a percent on the report card. Teachers discuss the seemingly subjective nature of assigning levels as no consistent criteria exists, and lastly teachers feel that most students are not capable of attaining a level three or higher. This thus partially answers the research question on the challenges teachers faced and the solutions found in implementing the science curriculum.

On the positive side, teachers discuss using levels most of the time as they are easy to use, that levels are clearly defined and therefore easy to discuss with the students and finally some teachers feel that whether levels or percents are used throughout the semester, there is little difference in the final percent recorded. This question thus partially answers the research question on the challenges teachers faced and the solutions found in implementing the science curriculum.

Teachers discuss the use of achievement levels in assessing the knowledge and skills expectations of the science and technology curriculum. Teachers discuss the extensive use of rubricks in labs, assignment, projects and presentations. Teachers discuss using three different percent ranges within each level as this decreases the subjectivity. Teachers also discuss that the method used to obtain a final mark is based on the most consistent level demonstrated and that the conversion of levels to percents is pre-determined at the start of the semester. Four teachers discuss not sub-dividing each level where level 4 is equated to 80-100%, level 3 to 70-79% and so on. Finally four teachers discuss using percents, not levels in tests and quizzes. This question thus partially answers the research question on the changes teachers made to adapt to the new science curriculum. The responses to this question were found to be unrelated to experience and specialization.

Question #9 What types of assessment are used to judge and analyse the skills of inquiry and design?

This interview question is aimed at addressing some of the issues relating to research questions 3: What changes have teachers had to make in order to adapt to the new curriculum? and, 4: What challenges has the new curriculum posed and what solutions have they found for these challenges?

Teachers discuss a variety of assessments used to analyse the skills of inquiry and design. These include: (i) assessment of group work (ii) assessment of independent work (iii) self and peer assessment and (iv) observation.

Assessment of Group Work:

Teachers discuss the assessment of the skills of inquiry and design in small group presentations, formal group presentations, project presentations, and the group work during labs. Small group presentations occur more frequently than the formal presentations which require more preparatory work and more teacher direction. Teachers discuss the use of labs with respect to the development of the skills of lab design and the inquiry into the scientific method. Teachers discuss the assessment of major assignments where the students have to design their own experiment to solve a specific problem. Teachers discuss doing a fair amount of group work because of the time saved as well as the sharing of knowledge between students.

> I like small group learning, I think that they can help one another. I think they develop social skills, it develops acceptance of the opinions of others that may differ from yours, that you can debate it without you being insulting, argumentative. I'm really big on small group,... I get them in their small group and then they'll stand up or they'll appoint a spokesperson from their group, to stand up in front and present their ideas and I'll evaluate that. (GN6)

Assessment of Independent Work:

Teachers discuss the independent assessment of the skills of inquiry and design through labs, projects and research projects, oral presentations, and oral testing. Students are individually assessed on their ability to design their own experiment, and test their hypothesis, students are assessed on their personal interpretations and connections made on their research projects, and orally tested to determine if they truly understand what was done.

Labs:

> ....after the unit on nature of science where they've taught the theory of scientific, scientific method and then we do a few demos, and then we'll do a few experiments and then I'll actually present the assignment. I want you to design experiment, show that design to me. ...I look to see that it's a reasonable design in terms of it having a purpose, hypotheses. I look to see that whatever procedure that they develop, someone tests that hypotheses. That's the key one, I think. Is to make a guess, then design a test to test it. To test that guess. (DY6)

Independent Projects/Research Projects:

> They did an independent project though for me and certain parts of our life sciences we had gotten through, to organs and we've gone through cells and tissues and they had to choose an organ and they had certain things they had to discover about it and that was

basically a research project. ....with their lab work, in their conclusions, there were questions that were worded where it was their opinion. ...and making connections and saying how they would either improve their lab next time or what worked and what didn't and why and that sort of thing. (AY5)

Oral testing/presentations:

Yes, oral testing would be part of it. Or even in something as simple as saying, okay, there's your project, tell me about it. Tell me about this. Tell me how this works. Explain it to me. Now, they're basing their explanation on this. If they can explain it to me properly, ...the scientific property method, but they will explain all the steps. And you say, okay, there's somebody who not only knows how to write the scientific method but has gathered knowledge from it and understands what they have done and the principles behind it. (IN6)

Self and Peer Assessment:

Teachers discuss having the students do self and peer assessments to judge and analyse the skills of inquiry and design. In the students' self assessment of their work, the teacher challenges the students' assessment if it is different from the teacher assessment. With respect to peer assessment, some teachers use it fairly often while other teachers seldom use it as a means of assessment. Most of the assessment is teacher directed.

Peer and self definitely come into assessment. Most of them have a good idea if what they have build is good or not and they have an idea of where that falls. When it comes to designing things, more often than not, if it stays together, and there is some thought to it, it gets a fairly high level from me because its just a matter of, they've put the work into it and they've attempted to apply the concepts. Because sometimes its hard to build stuff,... you can ask their opinion on what they think they've produced and that's a pretty good indicator of where they are. (BY5)

...depending on relationships and, oh this looks good, a lot of them don't take it [sic - peer evaluation] seriously, I find a lot of them just, they don't see any value in it and they don't

> take it seriously. And if its their friends, well, of course, they're not going to give them a low evaluation, you know, they're not going to be critical of anything. ... And even self evaluation, very few of them are really in tune with whether or not they've done what is required, even if they have a plan right in front of them and you can then go back and say, wait a minute you didn't do this whole section,...(CN5)

Observation:

Teachers assess the skills of inquiry and design when observing students working on activities and in group work. Teachers assess whether students are making connections, and their interactions in a group setting.

> Observation, just to sit back and see how the kids are making, if they're making connections and I mean, a lot of times, especially at this level, you can't really tell by their written work because often times they are working in groups and its not their work, but if you can sit back and observe, you can see if they are actually questioning, or actually participating or are they just getting it from their friends sort of things. (AY5)

Teachers also discuss their positive and negative feelings about their ability to develop the skills of inquiry and design in their students. No correlation was found between years of experience or being a subject specialist and the ability to develop these skills.

On the positive side, three teachers are confident in their abilities, and the abilities of their students to develop the skills of inquiry and design. These teachers discuss their comfort level and ease of use.

> I feel pretty comfortable about doing this because I've experienced this technique myself. I've had teachers teach me with this technique and I like the idea of asking students questions and having them explore and that's always sort of been my teaching style. (AY5)

> These kids are very used to it [the inquiry/design method]. They still, even with all of that are very concerned about the end product. What's the answer. That's what they are really

concerned about. But they have the skills and they have the background to be able to understand that even though they would like that perfect answer, that I might not get it and it might not be the same as theirs, and I don't know what the result is going in, and I shouldn't presuppose something before I know it. So these kids are actually pretty good at that. The honest to god truth is we are working with some pretty capable kids. (FN6)

On the negative side, three teachers feel that students need more opportunities to develop the skills of inquiry and design and that teachers would like some in-service in this area.

Sometimes letting go and letting the kids go solve the problems is not an easy thing to do especially when you have a lot of control in your class. Because basically you are giving control back to the kids. I don't , I'm not crazy about just letting kids go totally on their own, I think at this age level, like I said yesterday, you need some structure. You kind of guide them. But I'd like some help in that, basically is what I'm saying. (DY6)

In summary, teachers use a variety of assessments to analyse the skills of inquiry and design. These include assessment of group work, of independent work, self and peer assessment, and observation. Group assessment include small, large, formal, and informal group presentations and labs. Teachers discuss the use of labs to develop the skills of lab design and the inquiry into the scientific method. The assessment of group work is done frequently because of the time saved as well as the sharing of knowledge between students. The independent assessment of the skills of inquiry and design is done through labs, projects, and orally. Students are individually assessed on their ability to design and perform their own experiments, on their personal interpretations and connections made on their research projects, and orally tested to determine if they truly understand what was done. Self and peer assessment, most of which is teacher directed is used to judge and analyse the skills of inquiry and design. The teachers challenges the students' assessment if it is different from the teacher assessment. Peer assessment is used fairly often by some teachers and seldom by others. Teachers assess the skills of inquiry and design when observing students working on activities and in group work by assessing whether the students are making connections, and their interactions in a group setting. This question thus partially answers the research question on the changes teachers made to adapt to the new curriculum.

Teachers discussion concerning their positive and negative feelings about their ability to develop the skills of inquiry and design showed no correlation between years of experience or being a subject specialist and the ability to develop these skills. On the positive side, three teachers are confident in their abilities and the abilities of their students to develop the skills of inquiry and design. On the negative side, three teachers feel that students need more opportunities to develop the skills of inquiry and design and that some in-service in this area is needed. This question thus partially answers the research questions on the challenges teachers faced and the solutions found in implementing the science curriculum.

Question #10 What types of evaluation are used to judge and analyse the conceptual skills.

This interview question is aimed at addressing some of the issues relating to research question 3: What changes have teachers had to make in order to adapt to the new curriculum? The various types of evaluation used to judge and analyse the conceptual skills include using tests, quizzes, assignments, peer evaluation, labs and oral evaluation.

Tests:

All but one teacher, an experienced non-specialist, use tests to judge and analyse the conceptual skills. Teachers discuss testing at the beginning and/or at the end of a unit and that this type of evaluation is the only means of determining each individual student's knowledge and understanding. The responses were unrelated to experience and specialization.

> I might have a test depending upon what we covered. And different strands lend themselves to different things. I'm not sure I would do an actual unit test,... for structures because that would be a strange test to give. That's a paper test when a lot of its just building and applying those kinds of things. (BY5)

> I tend to go back to the formal testing and as I said, that can be done verbally, or in writing, I don't mind varying the way that I do that, but I think it has to be done individually. ....the impression that I've had in the last few years is , that people are

wanting to get away from that and its almost seen as that its not a good thing to do and I don't agree with that, I still think we need to have that component in there. (CN5)

Quizzes:

The majority of teachers use quizzes to judge and analyse the conceptual skills. Teachers discuss using quizzes frequently to evaluate the student's knowledge and understanding after every concept or a few concepts, that quizzes could be done in 5 - 10 minutes, and that quizzes could also be given on labs to determine whether the student was actively participating in the lab. The responses were unrelated to experience and specialization.

> Students write a fair number of quizzes in my class, but those are based on a lesson presented... on a specific day. So let's say at the end of the class, the last five or ten minutes, I want to see whether or not the students understood the content presented so I will do a classroom quiz. It might be true/false, multiple choice, a short question and answer, it's for me to assess immediately whether or not the concepts that I supposedly taught have been understood by them. (EY6)

> You do it on every unit. And the easiest way to do that is with quizzes rather than with a major test. I mean, major tests, are very high stress for kids, there's tons of marking in them, so you are better off to give quiz. Like when you do a little section, I give a quiz. It's a lot easier on you it's a lot easier on the kids. And they are much more relaxed. (IN6)

Assignments:

Four teachers discuss using assignments to judge and analyse the conceptual skills. Teachers discuss oral (presentations) and written work, small assignments, and group assignments. Students are given an open-ended problem/question and are asked to solve it by building/designing something, by writing a few paragraphs demonstrating their critical thinking skills and knowledge on how to solve the problem, and then presenting their findings and solution to the class. The responses were unrelated to experience and specialization.

> Small assignments. Again, I may pose a problem or a situation, and say, write me a couple of paragraphs on this, or what do you think of this, or how to you think you can you solve this, or do you agree with this. Why or why not. Take ten or fifteen minutes and write me half a page. Or, I may in a group, pose an open ended question and say to them, you have twenty five minutes to, and then I want you to come up here and I want the four of you to share with your class, the classmates,... I get to see, they talk about, you know, how they talked about things together, their thought processes, they're verbalizing what they're thinking. ...Sometimes, you know its an open ended question that isn't right or wrong. It's an opinion on something. ...But I like to hear kids explain to me. How. Hear them explain to me verbally, not just in writing, how they came to this conclusion . I think its, I think its fascinating for me to listen to how, cause they come up with stuff that never crossed my mind. (GN6)

Peer Evaluation:

Two teachers discuss using peer evaluation as a means of judging the students' conceptual skills. Students evaluate their peers' work and give them a mark. One teacher uses a rubrick and finds that some students are good at peer evaluation while other students are not good at it. The other teacher thinks that the kids are good at peer evaluation, and that they respect that their peers' feedback can provide useful information about their work.

> Sometimes its simple, like alright, here's the overall criteria or rubric, and give them a mark out of ten and then you have to write a comment, it could have been better because, or it was wonderful because, that kind of stuff. ... There's a few of them that are good at it. Some of them aren't very good at it at all. (HN6)

Labs:

Three teachers discuss using labs as a means of evaluating the conceptual skills taught. Labs are used to reinforce the conceptual skills.

> Labs. Looking at conclusions. Looking at their interpretation of their data. At this level I often look at their conclusions. I usually set labs up for them. They really don't know

how to set up a lab yet. And that's why I think grades 7 and 8 is the foundation time. I can't just teach it to them once and expect them to know it for ten months. I need to reinforce continually. (DY6)

Orally:

Three teachers discuss orally evaluating their students on their conceptual skills. Two of the three teachers are non-experienced specialist, and the third teacher is an experienced, non-specialist. Teachers may have the students do oral reports, they may have the students demonstrate their knowledge to a specific question orally, or have the students explain how/why something works.

Oh yeah, basically when they're working on a lab or a challenge of some sort, that's what I'm doing is wandering around and just saying, do you understand what you are doing here. So why are you doing that. You know, asking questions. ...Oh it does. I think so. I find that my science is taking a lot of time with their assessing this year. (AY5)

In summary, to evaluate the students knowledge and understanding of the concepts covered in the science and technology curriculum, the majority of teachers use tests and quizzes the most frequently. Teachers also assign open-ended problems, and the students' solution may include designing and building a model, summarizing the solution in writing, and presenting their findings to the class. Two teachers also use peer evaluation as a means of the students demonstrating their conceptual skills, validifying their knowledge, and providing and obtaining feedback to/and from each other. Labs are used to reinforce the conceptual skills. Lastly a few teachers also evaluate students' conceptual knowledge orally as it is an efficient means of deducing the students' conceptual knowledge to a specific question or problem. This question thus partially answers the research question on the changes teachers made to adapt to the new curriculum.

Question #11 At this time, is there anything else that you would like to add so that others might have a better perspective of the implementation of the new elementary school science curriculum?

The data derived from this question did not provide any additional findings or answers ti the four research questions.

Teachers discussion is divided into the positive and the negative issues. On the positive side, teachers' comments are divided into the following categories: The good aspects of the curriculum, the accepting of the curriculum, and finding support in each other.

The good things about the curriculum:

Two teachers discuss that hands on investigation and the inquiry and design process of learning helps the student learn by making connections and in the end become independent learners.

> ...if you are using the skills of inquiry and design, then, the students are going to learn the processes, the students are going to learn that way of thinking, which is going to help them in the long run anyways. They can follow that and they can understand that and they can make the connections. (AY5)

Accept the curriculum:

Two teachers discuss accepting the new curriculum for it is a good one and is providing a positive learning experience, doing the best they can, accepting that they are not going to cover everything, and that they need to re-evaluate the curriculum continually.

> I just think that, I mean I don't find the curriculum terribly onerous. And I'm not really struggling with it. I like the kinds of things that I'm doing with the grade seven curriculum and the kinds of things that I can do to meet those outcomes, and experiments. I think they're fun, my students seem to be pretty excited,...(GN6)

> The only thing that comes to mind is we have to accept that this is the new curriculum. I think there are some people who are still fighting the fact that we have to implement this and that's a foregone conclusion. ... And this curriculum makes us learn, I mean, there are horror stories of teachers who have had the same curriculum for you know, a hundred years, I mean I'm exaggerating, but it just feels like that. That they never change

anything. And what it has done, it has forced those teachers to make some changes and I think that has been for the better. I really do, I think that has been very positive. And it is a learning experience for us. And that's not a bad thing. (CN5)

Support each other:

One teacher discuss looking to each other for support through discussing with each other which areas of the curriculum are problematic, and finding support in these areas.

> And I've been guilty of feeling guilty because I didn't do a good job on a unit, and I think we have to look to each other for support, so that I will, in talking to another teacher say, geez you know, I really don't feel I did well with this unit and I've done that, and then I've had other teachers say you know what, we all feel that way. (CN5)

On the negative side, teachers' comments are divided into the following categories: The problems with the curriculum, the need for adequate funding, and the impossibility of covering the entire curriculum well.

The problems with the curriculum:

Two teachers discuss that there is too much material in the curriculum, the timelines are insufficient, that the curriculum is restrictive as current scientific issues that arise does not fit into the curriculum, as does an open science unit, that some units are theory laden, that 50% of the students will understand the expectations all the time and that although the curriculum's expectations are worded using "will", that some students will never get it, and that the new curriculum is simply a re-invention of the old with some basic concepts moved from one grade to the other.

> The problem is the amount of material and the timelines we have, its restrictive at times... and there is not the opportunity though when you try to find it to deal with current scientific issues and things that arise. ...And I wish, in fact, that there were fewer strands. And that there would be an opportunity, almost like an open science unit that would allow a teacher to cover, contemporary science issues or something to that degree.

Once again, you know, an experienced teacher will fit that in anyway. It's something to be aware of. (EY6)

Like I hate science that is theory. I just can't stand it. I do it but if I had a choice, I would do most science that is hands on. The physical, because its fun. It's fun for me too. The theory. Kids get absolutely bored to death with theory. And yet in a lot, some of the units, there is an awful lot of theory. ...However, its got its set of problems. In some of the areas, I look at some of the kids, and there is no way in this world, that they are ever going to hit those expectations. ____ About 50 percent of my kids will hit them all the time. But I've got a group of about I guess three or four percent that are never in this life get all those expectations. ... Yes. Fifty percent of my class will be exactly as the curriculum states. ...its just the way, its just their abilities. Most of it is sometime in the past, because either they didn't care or they got sick or whatever, that they are missing blocks in their information. And in a lot of cases, I don't have the time to go back... I'd rather have that the wording that a student shall which gives you some leeway, or is able to, but WILL means that every kid in the room, doesn't matter whether its grade one to grade eight, they will have all of these things known well. (IN6)

The need for adequate funding:

Four teachers feel that funding should be made available to implement the curriculum fully, and to teach the program so that students would have a better understanding of the material.

I just really want to see access to resources. For me, that's the big thing. I could do more in less time with the proper resources where I wasn't trying to jerryrig things and make do. Science is hands-on. In my mind if science isn't hands on it isn't very worthwhile. I don't believe science happens in a textbook. I can't be convinced of that by anyone and right now, I don't know, I don't think anybody wants to try. I don't think they agree either. And I think that's our issue. Give us the resources, we can implement it – even better. (GN6)

...you know the idea of going and buying all the resources yourself, and things like that, I mean, I've done that in the past where I've wanted to do something in class and then taken it out of my own expenses... But there are times this year that I've actually said to myself, no, you know what, I'm not going to go and buy that on my own, because I'm going to deliver this program the best I can with the resources I have here at school,... you can really get caught up in that in trying to get everything for your classroom. And, no, I think the school has to take some responsibility and the ministry has to take some responsibility for making sure that the money is there so that the resources are available to teach the programs. (CN5)

Impossibility of covering the curriculum:

Four teachers feel that it is impossible to cover all 5 strands of the curriculum, that there is too much material in the curriculum and too little time, and that possibly a teacher can do three strands extremely well.

I mean most people think it's going to be a lot, its going to be, I mean its going to be impossible to cover all five strands very thoroughly. You're going to have to pick and choose , you know, the most important concepts, the other ones you might be able to touch on, but to get all five strands, every single thing that they want, every single expectation that they list, I mean they have them in detail, not just in general but in detail, to do a lab or to do an investigation on every single one, in every, in all five strands, is very very difficult. (AY5)

When you've been at it awhile,... and like I say I've been in it for thirty years, and about every five years they are changing the curriculum, well, they don't change it, they just shuffle it, so at any given time I've taught any of these units, so I'm comfortable with it. Somebody who comes out of teachers college and takes a look at this thing and says you must teach this plus eight other documents like it, no wonder they panic. It's small wonder they panic. And especially since the expectation is that you want to do all five strands and they expect to be perfect. The sooner you realize that that's never going to happen in your teaching lifetime, the better off you are going to be. It's just not possible.

> You just don't have the physical time. Again, being, if you had a whole class of ninety percent achievers that were strictly academics, they never fooled around, yeah, you could probably do it, but what are the odds of ever having a class like that. I've never hit one. Yet. (IN6)

In summary, teachers' additional comments could be divided into the positive and the negative issues concerning the implementation of the elementary school science curriculum. On the positive side, teachers discuss the good things about the curriculum, accepting the curriculum, and supporting each other. There are a lot of positive things about the curriculum, including the opportunities the curriculum provides for hands-on investigations and learning the skills of inquiry and design. Teachers discuss accepting the curriculum, doing the best they can, and re-evaluating continually. Looking to each other for support, especially in problem areas or units is also seen as a need. On the negative side, teachers discuss the problems with the curriculum, the need for adequate funding, and the impossibility of covering the curriculum. The problems with the curriculum include insufficient timelines, restrictive and theory laden curriculum, unattainable expectations for about 50% of the students and a re-invented curriculum where concepts and units have simply been shuffled from one grade to the next. Teachers discuss the need for funding to implement and teach the curriculum fully as it was meant to be. Lastly, teachers feel that it is impossible to cover all 5 strands of the curriculum well, but that possibly 3 strands could be done well.

It should be noted that, although not a majority, four teachers feel that more funding is required to successfully implement the curriculum, and that there is too much material in the curriculum to cover in one term. Three of the four teachers that feel that more funding is required are experienced teachers and three of these teachers are not subject specialists. Three of the four teachers that feel that it is impossible to cover the curriculum are not subject specialists.

5 DISCUSSION AND CONCLUSIONS

5.1 Discussion

The four major questions addressed by this study were as follows:

1. What knowledge do teachers have of the implementation process?

When teachers were asked what they knew about the implementation process of the new curriculum, their discussion included the time frame for the implementation process, what they knew of that was done in the past, and their expectations for the future. All teachers believed that the implementation process was scheduled by the board for two to three years, and the majority of teachers planned to do so in three years.

> ...I know that our Board has implemented two strands this year, ... Next year they are implementing another two strands, and in the following year they are implementing the last strand. (AY5)

This supports Roberts and Roberts (1986) claim that implementation of a major innovation usually requires 3 - 5 years, and Hord et al., (1987) claim that change is "a process occurring over time" (p.6). All teachers were implementing the new curriculum and all were on schedule.

> Actually we have implemented the new curriculum fully. Even though we didn't have the requirements to do all five strands last year we did them. (FN6)

Since teachers were actually implementing the science curriculum, they were making "actual use of the innovation" as indicated by Fullan and Pomfret's (1975) definition of implementation. Also the fact that teachers report implementing the science curriculum as planned indicates a certain degree of mutual adaptation (McLaughlin, 1997) between teachers' capabilities and the boards' demands for a 3 year implementation within various school settings, ultimately resulting in a certain measure of success in the implementation process. Three teachers planned to cover all five strands after two years. Two of these three teachers were experienced in years, and one was a science specialist with little experience.

In the past, all but one teacher had received resources packages and textbooks. The resource packages were developed for teachers to support and provide tentative help in the implementation of the science and technology curriculum. Teachers also received grant money for texts and lab equipment. The majority of teachers had attended 1-3 workshops of either ½ day or 1 day on specific units or strands and/or the inquiry method organized by the board, OECTA, or by a textbook publisher. This supports Marsh and Willis' (1999) fidelity of implementation theory since the teachers in this study are treated as "passive recipients of the wisdom of curriculum developers." (p. 233) The limited role teachers had in the implementation process is evident as teachers were not a part of the planning phase with the developers, but adopted and implemented the curriculum in their classroom. Harris (2003) also discusses the limited role teachers had in the New South Wales history syllabus development where bureaucratic bodies were dictating not only what constitutes subject knowledge, but why and how it is best taught, learned and assessed, and it is these issues which creates conflicts or acceptance. The majority of teachers in this study seemed to accept their roles and responsibilities.

Most teachers were unsure about their board's future plans.

> ... but what's the next step. What are you [the board] going to do to prepare us properly for the new curriculum .... I just don't see that happening. (DY6)

Their expectations for the future included more in-service, workshops, professional development, teacher resources, equipment, and textbooks. None of the teachers were aware of any on-going PD planned for the future.

Fullan (1992) states that one of the main reasons why "Educational change fails more times than it succeeds .... is that implementation - or the process of achieving something new into practice has been neglected" (p vii). This study demonstrates that the implementation process has been somewhat neglected but the teachers are actually adapting to the changes and implementing the science curriculum as planned.

In summary teachers' knowledge of the implementation process included:

• The time frame - A two to three year time frame for the process

• What was done in the past? Teacher support was provided through the allocation of resource packages, textbooks, grants for texts and lab equipment and professional development.

• What will be done in the future? Most teachers are unsure of the board's future plans but expect workshops/professional development, and resources (textbooks, lab equipment, and teacher resources).

2. What knowledge do teachers have of the new curriculum?

The Structure:

Teachers' discussion on the advantages of implementing the new curriculum bring to light teachers' knowledge of the curriculum. Most science teachers were aware that the continuity of the curriculum from Grades 1 to 8 means that there is little overlap from grade to grade. Most teachers also saw the positive aspects of the increased structure of the curriculum not influencing students transferring from class to class or from school to school, that the curriculum is laid out point by point, and that there is no guesswork.

> ...I like the structure of it. I like to know what I'm supposed to be teaching, there's no guesswork in it any more .... so therefore when I'm looking for resources, I can be very specific in what I'm looking for, and gear experiments to producing those results to show students different things. So I think its an advantage.(CN5)

The standardization of the curriculum across the province and the consistency of the report card also made sense to the teachers as all students are doing the same thing and their progress is reported the same way.

> .... the new report card, for all the complaining about it, is the same across the province. .... but the bottom line is when you get a report card from a student outside of your jurisdiction and you read it, it makes sense. Because you're using the same one. So I like the consistency. (FN6)

All teachers involved in this discussion, responded in a similar way. Ornstein and Hunkins (1993) state that teachers resist change for many reasons two of which are "lack of ownership" and "lack of benefit". In this study, the teachers have taken ownership and see the benefit of the implementation of the science curriculum. No relationship was found between their answers and the two factors of years of experience and specialization.

The Content:

Teachers demonstrated their knowledge of the curriculum through their discussion on the changes that have occurred in the content of what is being taught and learned. The majority of teachers felt to varying degrees that some of the concepts in the curriculum are being introduced at an earlier grade and are thus seen by the students as more complex and challenging. It should be noted that one of the factors that assisted in the reported success of change through Curriculum Alignment (Marsh & Willis, 1999) was "The content of the reform was targeted at all students and constituted a toughening of existing academic programs." (p. 255) Vinovskis's (1996) definition of systemic reform also includes a "challenging curriculum" (p. 73). The content is also more detailed, and contains more theoretical knowledge. The well laid out expectations for each grade make it clear to the teacher what needs to be taught by the end of each grade and this was seen as positive.

> I think the content...... it is more specific. I think in a lot of areas, the content seems to have, the bar seems to have been raised somewhat, that our expectations have risen, the benchmark is higher, now,... (GN6)

According to Ornstein and Hunkins (1993) one of the many reasons why teachers may resist change is the "lack of benefits" (p. 307) for student learning and teacher rewards as in the detailed nature of the curriculum which may restrict the teacher from teaching what they feel is important and the changes will result at least temporarily in an "increased burdens" (p. 307) on most teachers. Unlike Ornstein and Hunkins, the teachers in this study see the benefits of the detailed nature of the curriculum. Two out of three inexperienced teachers felt that course profiles would be useful and this was to be expected although no conclusions can be made from such a small sample. The one inexperienced teacher that did not comment on this issue was a science specialist which could possibly explain why this teacher did not see a need for profiles.

Since most of the teachers were knowledgeable about the curriculum and felt that they were implementing it without difficulty it is hoped that the intended, the taught and the learned curriculum are all being achieved by the teachers and students (Rosier & Couper, 1981).

In summary, teachers' discussion on their knowledge of the new curriculum centred around the changes in the content of the curriculum (what is being taught and learned).

• Teachers have noted that the structure of the new curriculum includes more continuity (less overlap), increased structure, a detailed layout with no guesswork, and its standardized nature.

• The majority of the teachers feel that some of the concepts in the curriculum are being introduced at an earlier grade and are therefore seen by the students as more complex and challenging.

• The content is also seen by the majority as more detailed, which is seen as positive, and it also contains more theoretical knowledge.

3. What changes have teachers had to make in order to adapt to the new curriculum?

Means of Instruction:

The changes that had occurred in the means of instruction included a few broad changes with the majority of teachers allowing learning to occur in small groups, developing the students' skills of scientific inquiry and technological design, providing more opportunities for hands-on investigations, developing the students' questioning skills, and less classroom structure specifically with respect to labs and the inquiry and design method when this is being done.

> .... This is what we want ... are trying to find out. And say, design the experiment .... the first time, they looked at me like I had asked them to explain quantum physics to them. They said, well, how do we do the experiment. I said, no, I'm asking you, how do we do the experiment. ..... .Of course, its going to take longer than me just telling them how to do it. But it was better. It was their experiment. They designed it. And then they had no reluctance to bring it up to the front and show. Because it's "look what we did". (GN6)
> ... you have in some cases, have to go backwards and actually teach kids how to do this. If I back up and teach them, how do you take something and ask questions about it. And what you do is you start with a problem, ... and you say okay people, what three

> questions could you ask about that particular problem. Alright, what's wrong with these questions. How could they be reworded differently ... (IN6)

This supports the goals of Canadian science education set forth in the *Common Framework of Science Learning Outcomes, K - 12: Pan-Canadian Protocol for Collaboration on School Curriculum* which was released by the Council of Ministers of Education, Canada (1997) specifically with respect to developing in students a sense of "wonder and curiosity" (p.5), enabling students to solve problems and preparing students "to critically address science-related" problems (p. 6). This study also supports one of the goals of science education in Ontario which is to "develop the skills, strategies, and habits of mind required for scientific inquiry and technological design" (Ministry of Education and Training, 1998b, p. 4). The Stages of Concern (SoC) sequence shown in Figure 2 (reprinted from Marsh & Willis, 1999, p. 246) provides valuable insights into the concerns of teachers during the introduction of an innovation into the classroom. From the changes that occurred, teachers are either at a stage 3 (management) or 4 (consequence), where in stage 3 the teacher is focused on the processes and tasks of using the innovation and resources, and in stage 4 on the impact of the innovation on students.

Methods of Evaluation:

Teachers had to make changes in their methods of evaluation. The majority (six) of teachers used rubrics and self and peer evaluation extensively and this appears to be unrelated to experience and specialization.

> ....the kids are given what's expected of them level wide with the rubrics .... most of them understand [it], they've had it for at least two years, they've got an idea of what a level would look like and what is expected of them. (BY5)

Assessment of Inquiry and Design:

Another change that teachers have had to make in order to adapt to the new curriculum was in the deliberate assessment of the skills of inquiry and design. Teachers use a variety of assessments to analyse the skills of inquiry and design. These included assessment of group work, of independent work, self and peer assessment, and observation. This is supported by the

National Science Education Standards (2000) assessment formats and procedures in Table 8 which show the various formats used to assess student learning (multiple choice, true/false, matching, essays, investigations, research reports, projects, portfolios, journals, labs, and notebooks) . Group assessment included small, large, formal, and informal group presentations and labs. Teachers discussed the use of labs to develop the skills of lab design and inquiry into the scientific method. Connelly (1987) believes that one of the main needs in science is for students to learn to deal with problems in a hands-on scientific fashion, but time constraints result in labs that confirm readily predictable outcomes and require no concept of the scientific method. The teachers in this study are thus fulfilling this need. The assessment of group work was done frequently because of the time saved as well as the sharing of knowledge between students. The independent assessment of the skills of inquiry and design was done through labs, projects, and orally. Students were individually assessed on their ability to design and perform their own experiments, on their personal interpretations and connections made on their research projects, and orally tested to determine if they truly understood what was done.

> Now the assessments that I use again are required by the ministry. They are independent work, which involves a variety of assignments, including lab work, and group work has to be evaluated. Again that is done using kind of a two tier level, its not just the product, it's the process. So the students are evaluated for their individual input, which is marked on going, as well as the final product. (EY6)

> ...and making connections and saying how they would either improve their lab next time or what worked and what didn't and why and that sort of thing. (AY5)

Self and peer assessment, most of which was teacher directed was used to judge and analyse the skills of inquiry and design. The National Science Education Standards (2000) also supports the use of a variety of assessments from guided (structured) to open (no structure). The teacher challenged the students' assessment if it was different from the teacher assessment. Peer assessment was used fairly often by some teachers and seldom by others. Teachers assessed the skills of inquiry and design when observing students working on activities and in group work by assessing whether the students were making connections, and their interactions in a group setting.

This is consistent with the National Science Education Standards (2000) which states that "assessment determines whether students can generate or clarify questions, develop possible explanations, design and conduct investigations, and use data as evidence to support or reject their own explanations" (p. 75).

Evaluation of Conceptual Skills:

To evaluate the students' knowledge and understanding of the concepts covered in the science and technology curriculum, the majority of teachers used tests and quizzes the most frequently.

> I tend to go back to the formal testing .... the impression that I've had in the last few years is , that people are wanting to get away from that and its almost seen as that its not a good thing to do and I don't agree with that, I still think we need to have that component in there. (CN5)

Teachers also assigned open-ended problems, and the students' solution may include designing and building a model, summarizing the solution in writing, and presenting their findings to the class.

> ...you can also have design challenges at the end of every unit .... design and build artificial skin. Some of them it would be hard to do, to build and those kind of things, just for time and space, but it would give you an idea, to give them an open ended question to say, here's a problem, how are you going to solve it. That kind of idea. Because it's a matter of applying all these different concepts. (BY5)

The use of open-ended problems is even more prevalent in the current curriculum. In this study the use of open-ended problems supports the constructivist theory of learning and the methods of instruction such as Predict-Observe-Explain which places more emphasis on the formation of concepts in science in the learner during the teaching of science (Chin et al., 1997) and is highlighted again by Chin et al. when he raises the question "What emphasis should be placed on exposing students to authentic science activities?" (p. 11). Two teachers also used peer evaluation as a means of the students demonstrating their conceptual skills, validifying their knowledge, and providing and obtaining feedback to/and from each other. Labs were used to reinforce the conceptual skills. Lastly a few teachers also evaluated students' conceptual knowledge orally as it is an efficient means of deducing the students' conceptual knowledge to a specific question or problem. The Stages of Concern (SoC) sequence (reprinted from Marsh & Willis, 1999, p. 246) provides valuable insights into the concerns of teachers during the introduction of an innovation into the classroom. From the changes that occurred, teachers are either at a stage 3 (management) or 4 (consequence), where in stage 3 the teacher is focussed on the processes and tasks of using the innovation and resources, and in stage 4 on the impact of the innovation on students.

Use of Achievement Levels:

Teachers assessed and evaluated the students using a number of tools one of which is the use of achievement levels (1 - 4) shown in Table 12 (reprinted from Ministry of Education and Training, 1998b, p. 13). Teachers' discussion on the various ways they had used achievement levels in assessing the knowledge and skills expectations of the science and technology curriculum clearly showed the changes they had to make to adapt to the current curriculum. Teachers discussed the extensive use of rubrics in labs, assignment, projects and presentations. Teachers discussed using three different percent ranges within each level as this decreased the subjectivity. Teachers also discussed that the method used to obtain a final mark is based on the most consistent level demonstrated and that the conversion of levels to percents is pre-determined at the start of the semester.

> ...in actually some ways, as you become more familiar with it, you can assess things a lot quicker, you can almost scan something and in a couple of minutes and you can decide what level it's at. So maybe to some degree it's not too bad. (EY6)

Four teachers discussed not sub-dividing each level where level 4 is equated to 80-100%, level 3 to 70-79% and so on. Finally four teachers discussed using percents, not levels in tests and quizzes. No relationship was found between the various ways achievement levels are used to assess knowledge and years of experience or specialization.

At this stage in the implementation process it can be said that teachers felt that they are heading towards the successful implementation of the science curriculum by a process of mutual adaptation (McLaughlin, 1976/1997). This process involves the modification/adaptation of the design of the implementation of science, of the school setting, and of individual teachers and administrators during the course of the implementation. Although teachers have had little input into the development of the science curriculum, the majority have adapted to and implemented the curriculum wholeheartedly unlike Ornstein and Hunkins' (1993) study where they state that teachers may resist change because of "lack of ownership".

The data collected from the assessment of inquiry and design and the evaluation of conceptual skills can not only be used to determine grades, guide student learning, and evaluate the effectiveness of the instruction but to plan lessons, evaluate the curriculum and inform policy, and assist in the determination of where resources should be allocated. (National Research Council, 2000)

In summary, teachers' discussion on the changes that they have had to make in order to adapt to the science curriculum include:

- Changes have occurred in the means of instruction and these include allowing learning to occur in small groups, developing the students' skills of inquiry and design, providing more opportunities for hands-on investigations, developing the students' questioning skills, and less classroom structure specifically with respect to labs and the inquiry and design method of instruction.
- The majority of teachers use rubricks and self and peer evaluation extensively.
- The majority of teachers are now deliberately assessing the skills of inquiry and design and use a variety of assessments to do so: assessment of group work (small, large, formal, informal, presentations and labs), independent work (labs, projects, orally), self and peer assessment, and observation.
- The majority of teachers use tests and quizzes the most frequently to evaluate the students' knowledge and understanding of concepts covered in the science curriculum. The use of open-ended problems (in technological design and labs) is even more prevalent in the current curriculum.
- Teachers are using achievement levels, and in various ways in assessing the knowledge and skills expectations of the science and technology. Four teachers use percents only in

tests and quizzes.

4. What challenges has the new curriculum posed and what solutions have they found for these challenges?

Teacher's Roles and Responsibilities:

The majority of the teachers discussed their roles as developing an in-depth knowledge and understanding of the curriculum in order to deliver the curriculum.

> ... my role, is developing my own knowledge base and resources and whatever I possibly need, gathering materials in order to be able to deliver it to the students. (CN5)

Teachers discussed the delivery of the curriculum to students in order for the students (a) to understand the curriculum, and make connections (b) to challenge the students to foster problem solving and critical thinking skills, and c) to assist students to become independent thinkers and learners.

> I think they want us in this to challenge our kids ... to create a more challenging environment. ...to foster a little bit more creative problem solving. And present that to kids who may not have normally experienced those sort of situations. ...to get them to start thinking rather than just waiting for information to be delivered to them, to find out themselves, or to create or solve a problem on their own. Or through a group. (DY6)

The Stages of Concern (SoC) sequence shown in Figure 2 (reprinted from Marsh & Willis, 1999, p. 246) provides valuable insights into the concerns of teachers during the introduction of an innovation into the classroom. From the changes that occurred, teachers are either at a stage 3 (management) or 4 (consequence), where in stage 3 the teacher is focussed on managing the task, and in stage 4 on the consequence of the innovation on students. The majority of teachers felt that in order to cover the entire curriculum, they needed to integrate the curriculum, as there is insufficient time to do all five strands of the curriculum and do them well.

> I mean, there are a lot of expectations in all of the curriculum. And its difficult to cover.

> ... What you do is you learn to combine things, to meet outcomes ... that maybe demonstrate more than the one thing .... Integrate within the strand. And also between strands. (GN6)

This is consistent with Ornstein and Hunkins' (1993) claim that the changes that teachers have to make in the implementation process will result, at least temporarily in an "increased burden." This is also supported by Lafleur and Tucker's (1997) study of the experiences of teachers implementing the Common Curriculum where teachers found that the use of time effectively, efficiently and productively was a daily challenge, as there was never enough time for timetabling, planning, or organization and teaching of the curriculum and student-centred integration of learning was needed for implementation. Teachers discussed accepting the curriculum, doing the best they could, and re-evaluating continually. Looking to each other for support, especially in problem areas or units was also seen as a possible solution.

> The only thing that comes to mind is we have to accept that this is the new curriculum. I think there are some people who are still fighting the fact that we have to implement this and that's a foregone conclusion. ... And this curriculum makes us learn, ... And that's not a bad thing. (CN5)

Sparks and Loucks-Horsley (1989) believe that it is the companionship or peer coaching among individuals that will facilitate change. The Stages of Concern (SoC) sequence provides valuable insights into the concerns of teachers during the introduction of an innovation into the classroom (Hall, Wallace & Dossett as cited in Marsh & Willis, 1999). From the changes that occurred, teachers are at stage 5 where the focus is on collaboration and cooperation with others. The findings from this study is also consistent with Fullan and Stiegelbauer's (1991) claim that the more open to change teachers are individually as well as collectively in a collaborative environment the more likely change will be facilitated and that it is very important that the challenges they experience be seriously addressed. Teachers' responses to their role in the implementation of the science and technology curriculum were unrelated to experience and specialization.

Barriers to Implementation:

The majority (six) of the teachers felt that having a science background (knowledge and understanding of science), or being qualified in science would help in implementing the new curriculum, "...And you know, as far as being qualified in science, I think it would be a definite asset," (CN5), and the findings from the pertinent questions in this study showed that most of the teachers, 5 of whom were generalist teachers, were knowledgeable about the new curriculum, and were implementing it without difficulty. It should be noted that nine teachers is a small sample and a larger more representative sample is needed to draw a definite conclusion. Also, the fact that the majority of these teachers are generalist not science teachers supports Chin et al.'s (1997) claim that elementary science in most Ontario schools is taught by generalist teachers and Ornstein and Hunkins' (1993) claim that few elementary teachers are skilled in science and for most will require a lot of revision and review. The findings from this study are consistent with those of Harlen and Holroyd's (1995) 2-year study by the Scottish Council for Research on 514 primary teachers' understanding of concepts in science and technology where it was found that teachers that had done science beyond secondary school had a better understanding of science than teachers with no science background. However, there were some teachers with no science background, but yet understood the big science ideas. The data from the Harlen and Holroyd's study also showed that many teachers had a sound grasp on general knowledge which allowed them to teach science and technology with a fair degree of confidence. This suggests that the generalist teachers from this study either understood the big science ideas, or had a good grasp on general knowledge. Proudford's (2003) study (Table 13) also showed that lack of understanding of the concepts, and of the implementation process were major barriers to implementation. Thus if these barriers were removed, this would facilitate implementation.

Since most of the teachers were knowledgeable about the curriculum and were implementing it without difficulty it is hoped that the intended, the taught and the learned curriculum are all being achieved by the teachers and students (Rosier & Couper, 1981).

In their discussion on the disadvantages of implementing the new curriculum, most teachers said that they would like more resources to help them to implement their lessons, their labs (materials and space), and their assessments and evaluations.

> ...it needs the equipment, and it needs the textbooks, resource materials and it needs

> training of the teachers in a lot of cases. ...there is no lab .... there's no electricity, there's no running water that's convenient, etcetera. An elementary school is not set up for a science program ... (HN6)

The curriculum was also seen by most teachers as time intensive as is consistent in the Lafleur and Tucker (1997) study, and challenging for the average student. Similarly, Proudford (2003) in her Queensland study of the restructuring of the 1-10 curriculum identified that major barriers to implementation include the subjective/emotional realities of workload and stress and the resource barrier of insufficient time to allocate attention to all the Key Learning Areas (Table 13).

> There's not enough time to cover all the aspects. I mean that, but then you, that falls back onto what sits in your class. If you have a cracker jack class, then you will finish it. If you have your average class, which is high, medium and low, then you basically try to work to the middle, and you may get finished if you cut some stuff out. ... You have to know your class and what they are capable of. (IN6)

In addition to these challenges, most teachers viewed the results of standardized testing as potentially casting an unfair light on the student, the teacher, and the school. Teachers' discussion on the disadvantages of implementing the current curriculum were unrelated to the factors of interest to this study - experience and specialization. Proudford (2003) in her Queensland study of the restricting of the 1-10 curriculum found that one of the major barriers to implementation was resources - insufficient resources; and time to develop understanding and confidence, time to plan and time to allocate attention to all the Key Learning Areas (Table 13).

When teachers were asked what their main concerns were concerning the implementation of the science and technology curriculum, a few teachers felt that more inservice was required in order to prepare teachers for the new curriculum.

> ... a little bit of in-servicing in terms of how we can address the expectations in skills and knowledge, maybe some in-servicing on integration, on how maybe we can cover two at once, cover skill and a concept. That would help. (DY6)

Hendrickson, O'Shea, Gable, Heitman and Sealander (1993) believe that a favourable means of implementing new programs with the final aim of improving classroom instruction is through in-service workshops that are effective and not the traditional quick but inadequate and ineffective in-service training sessions (Englert, Tarrant, & Rozendal, 1993). Proudford's (2003) study on building professional learning communities for curriculum change found that one of the major barriers to implementation was inequitable inservice (Table 13). Thus one of the major factors facilitating implementation in Proudford's study is professional development and includes inservice, workshops in school time, workshops to discuss concerns, professional assistance in class and ongoing support (Table 14). The majority of teachers felt there was a need for more textbooks, equipment and space for a science lab. Teachers' main concerns seemed to be unrelated to experience and specialization. Harlen and Holroyd's (1995) two year study by the Scottish Council for Research on 514 primary teachers' understanding of concepts in science and technology found that the teachers wanted help in the following areas:

> "in-service courses, print-based resources, time to think and prepare, more and improved equipment, a school policy on what to teach and when, advice from specialists, and improvement in coordination and support within the school, pre-service science education courses. ...introducing and managing practical investigations, assessment and recording.(p. 7)

Most of the help that teachers are asking for in Harlen and Holroyd's study is the same as in this study. This supports Fullan and Steigelbauer's (1991) and Proudford's (2003) claim that the facilitation of new policies and legislation can be favourably affected by supports such as resources and professional development. It also supports McLaughlin's (1976/1997) theory on the use of staff training as a strategy for implementation.

The Inquiry Method as a Means of Instruction:

One of the major challenges that the current curriculum has posed to teachers is the use of the inquiry method as a means of instruction. The teaching emphasis of the new curriculum is perhaps best summarized in *The Ontario Curriculum Grades 1 - 8: Science and Technology* (Ministry of Education and Training, 1998b) by the following general statement: These goals "can be achieved simultaneously through learning activities that combine the acquisition of knowledge with both inquiry and design processes in a concrete, practical context." (Ministry of

Education and Training, 1998b, p. 4). What is of particular relevance for this study is that the literature does give evidence that inquiry oriented teaching is "effective in fostering scientific literacy and understanding of science processes, . . . , critical thinking, . . . , positive attitudes toward science" (Haury, 1993, p. 2) among other things. The National Science Education Standards (National Research Council, 1996) states that "science is an active process" (p. 2), and that "learning science is something that students do, not something that is done to them. "Hands-on" activities, while essential, are not enough. Students must have "minds-on" experiences as well" (p. 2), and that "inquiry is central to science learning [and teaching]" (p. 2). Inquiry in the Standards document is treated both as a learning goal and as a teaching method. In this study teachers are aiming to assist the student in developing the fundamental abilities to do scientific inquiry (Table 2) and the fundamental understandings of scientific inquiry (Table 3) in Grade 8. Although some teachers were finding the construction of the inquiry and design method of learning overwhelming, or had not implemented it at the time of the study, the majority saw it as a positive change and were confident in their abilities and the abilities of their students to develop the skills of inquiry and design.

> ... it's hard to set up an inquiry model of things .... All kinds of logistical things, including lack of equipment, that make this whole outfit extremely hard to do. It's almost like somebody said, okay we're going to design this to cause the system to fail so that we can say there's a big problem in education. (HN6)

The less experienced teachers (three) were less positive about fostering the inquiry and design method in their classroom and these three teachers felt that students need more opportunities to develop the skills of inquiry and design and that some in-service in this area was needed. This appears to be a reflection of their relative inexperience. Teachers' discomfort with the inquiry method supports Ornstein and Hunkins' (1993) finding that obstacles to inquiry may be related to "insecurity" (p. 307) and "chaos"(p. 308). The inquiry centred classroom is not as structured as has been the case in the classroom of the past and can be perceived as requiring a sounder grasp of science fundamentals.

> I found that in my first couple of years, when you are teaching some things like science, I

did structure the classroom a lot more 'till I got more familiar with how the students would cooperate. My classes are a little bit more open right now, basically, because I know what works and what doesn't work. ... So I think that would probably have to do with the experiments and comfort level of the teacher in how the classroom operates. (EY6)

Teachers' discussion concerning their positive and negative feelings about their ability to develop the skills of inquiry and design showed no relationship between years of experience or being a subject specialist. Because of the general nature of the teaching standards in Table 4, the National Science Education Standards (National Research Council, 1996) proposed the more specific and helpful essential features of classroom inquiry (Table 5) with the learner as the focus. These five essential features help students to "develop a clearer and deeper knowledge of some particular science concepts and processes" (National Research Council, 2000, p. 27). Table 6 describes variations in the amount of structure, guidance, and coaching the teacher provides students for each of the five essential features of classroom inquiry as noted in Table 5. Inquiries can also be labelled as "open", left-hand column in Table 6 or "guided", right-hand column, and refers to the degree of structure and direction provided by the teacher. It should be recalled that "An instructional model incorporates the features of inquiry into a sequence of experiences designed to challenge students' current conceptions and provide time and opportunities for reconstruction, or learning, to occur (Bybee, 1997)" (National Research Council, 2000, p. 34). Table 7 includes the components that are shared by instructional models and has many common features with the essential features of classroom inquiry in Table 6. Two of the features of inquiry from Table 7 include the hands-on experiences and the building of models to solve problems through technological design. This is also evident in Table 9 (Ontario English Catholic Teachers Association [OECTA], 1998, p. 5) which shows the technological component of science includes students seeking the answer to the question how, designing devices, products or systems, and building and testing the design. The Assessment of Science and Technology Achievement Project (ASAP) also developed achievement levels (1 - 4) to determine whether certain skills and strategies for inquiry and design were being met (Table 10) (reprinted from Ministry of Education and Training, 1998a, p. 86). It was observed in Tables 6, 7, 9, and 10 that the central elements of Inquiry and Design are: "understanding the problem, making a plan, carrying out the plan, and looking back" (Ministry of Education and Training, 1998a, p. 40).

The majority of teachers were also developing the students' questioning skills as this helps students to learn how to learn, and it is also a skill intertwined in the inquiry and technological design method of learning. *The Ontario Curriculum, Grades 1-8: Science and Technology* (Ministry of Education and Training, 1998a) stresses the importance of proper teacher questioning style to guide students through the inquiry process of solving the problem. Teachers need to ask students the most relevant question at the appropriate time based on what stage of the problem solving process the student is at. Appropriate questions that the teacher might ask at each of these stages of inquiry will be found in Table 11 (reprinted from Ministry of Education and Training, 1998a, p. 39). The challenges of using the inquiry method in teaching could be addressed using two of the three strategies that McLaughlin (1976/1997) identified as critical in successful implementation: Local Material Development, and Staff Training.

> In Local Material Development, the staff would spend a substantial time developing materials [on inquiry] to use in the classrooms, as this process appears to be a critical part of the individual learning and development necessary for significant change. In Staff Training, the "resocialization" of teachers is necessary. Even willing teachers have to go through a *learning (and unlearning) process* in order to develop new attitudes, behaviours, and skills for a radically new role [in this case the use of the inquiry method in their classroom]. Concrete, inquiry-based training activities [on the inquiry method], scheduled regularly over the course of project implementation provide a means for this developmental process to occur. (p. 172).

Use of Achievement Levels - its Challenges and Solutions:

One of the challenges that teachers faced with the new curriculum was the use of levels in their methods of assessment. Teachers' opinions concerning the use of achievement levels in their methods of assessment were divided. The majority of teachers had both positive and negative opinions about the use of achievement levels. On the negative side teachers questioned the contradictory method of assessing using levels, but recording a percent on the report card.

> If I'm going to report in percentages, it seems kind of goofy to evaluate in a level and then during this magical formula, convert it to a percentage, because I might do it

different than you would do it , than someone else would do it. (BY5)

Teachers discussed the seemingly subjective nature of assigning levels as no consistent criteria exists.

I think we have a lot of work at getting better at using levels and understanding what they mean and just being consistent with what they are. (CN5)

The assessment formats and procedures in Table 8 (National Research Council, 2000), not only show the various formats used to assess student learning (multiple choice, true/false, matching, essays, investigations, research reports, projects, portfolios, journals, labs, and notebooks) but the increasing challenges teachers face as one moves from the left to the right side of the table as the outcome of assessment goes from right/wrong to needing criteria to determine a grade or level which then introduces some degree of subjectivity. The achievement levels for science and technology, grades 1-8, used by teachers teaching the Ontario Curriculum (Table 12 reprinted from Ministry of Education and Training, 1998b, p. 13) not only show the various knowledge and skills students are expected to achieve but also the increasing challenges that teachers face as one moves from Level 1 to Level4, where the outcome of the assessment increasingly requires a criteria to determine a level or a level within a level which then introduces some degree of subjectivity. Effective assessment will therefore require standards that teachers agree on at the school or district level. Lastly teachers felt that most students are not capable of attaining a level three or higher. These challenges that the majority of teachers faced in the use of levels led to teachers seeking solutions by looking for the positives of using levels.

On the positive side, teachers discussed using levels most of the time as they are easy to use, that levels are clearly defined and therefore easy to discuss with the students and finally some teachers felt that whether levels or percents were used throughout the semester, there was little difference in the final percent recorded.

I gave it a one, two, three, four achievement level the majority of the time. I seldom put a number mark down, like a percent or something, I seldom do that any more .... and I think it actively reflects what the students did and what the students demonstrated they knew without a test. A test is memory work. (GN6)

No relationship was found between the teacher's use of achievement levels and experience and specialization.

The challenges in the use of levels could be addressed using the three strategies that McLaughlin (1976/1997) identified as critical in successful implementation: Local Material Development; Staff Training; and Adaptive Planning and Staff Meetings.

> In Load Material Development, the staff would spend a substantial time developing materials [on the use of levels for classroom use]. In Staff Training, concrete, inquiry-based training activities [on the use of levels], scheduled regularly over the course of the implementation provide a means for this developmental process [of learning (and unlearning)] to occur. In Adaptive Planning and Staff Meetings past research on the implementation is almost unanimous in citing "unanticipated events" and "lack of feedback networks" as serious problems during project implementation. Routinized and frequent staff meetings combined with on-going, iterative planning [on the use of levels] can serve to institutionalize an effective project feedback structure, as well as provide mechanisms that can deal with the unanticipated events that are certain to occur. (p. 170-172)

This appears to be a good strategy for solving the challenge of the successful use of inquiry since it is cross-curricular, and across all grades. The National Science Education Standards (National Research Council, 2000) on assessment discusses the increasing challenges teachers face as the outcome of assessment go from right/wrong to needing criteria to determine a grade or level which then introduces some degree of subjectivity. Thus the effective assessment using levels will therefore require mutually agreed upon standards to remove possible subjectivity.

Methods of Evaluation - Its Challenges:

Only two teachers discussed changes that have occurred in the methods of evaluation. One teacher felt that one of the changes that had occurred in the evaluation process was the decreased accountability on the students' part as a teacher has to give the students many opportunities to submit late work. Another teacher felt that one of the changes that has occurred is that the various methods of evaluation are not considering the process, only the product. Although two teachers are just a small proportion of the sample size, the challenges faced were felt to be important enough to be mentioned. The changes that have occurred in the methods of evaluation appear to be unrelated to experience and specialization.

Administrative Assistance:

The assistance that the teachers received from administration varied widely: from administration being very supportive but no money, to very supportive in all respects, to not a lot of assistance from administration. Teachers' discussions concerning the assistance that they had received from administration were not related to the factors of interest to this study - experience and specialization.

The majority of the teachers felt that the board could provide the funds to supply equipment and materials for a science lab as well as teacher and student textbook related resources.

> As far as how the money works, having the books for the kids would be helpful as well. ...but the materials and things for the lessons, those kinds of things [are] just a basis to work from, where I'm not reinventing the wheel. Every unit I have to think of a magical way to piece it together for seven weeks .... I would take a science room ... ...over textbooks I am sure ... (BY5)

The majority of teachers felt that there is a great need for teacher training and development in the effective use of the curriculum document in the science and technology area, specifically with respect to teaching science concepts effectively in a regular or split grade classroom and the development of the skills of inquiry and design.

> ...they could just sponsor and just support even board level inservicing. ...I would just like to see their curriculum people spend a little, maybe plan, a little more indepth inservicing. ... kind of get ideas on how we can go about teaching this new curriculum without it being just the delivery of concepts and the delivery of information. Because really its information loaded curriculum as far as I'm concerned and there has to be different methods of getting that across to young kids ... I think one of the things for me, personally, would be the inquiring design skills. How can I get kids to learn the

curriculum through their own initiative or their own ability to solve problems. (DY6)

The three strategies of Local Material Development; Staff Training; and Adaptive Planning and Staff Meetings could be used for successful implementation (McLaughlin, 1976/1997). Inquiry, one of the many teaching strategies is a central part of the science teaching standards. The inquiry component is clearly seen in Table 4 which gives a comprehensive listing of the science teaching standards, where the standards state that teachers of science "plan an inquiry-based science program", "focus and support inquiries", and "encourage and model the skills of scientific inquiry."(National Research Council (1996)). Teachers' discussion concerning what the school board could do to enhance the implementation process included the challenges that the teachers faced and the solutions that they felt were needed. Their responses on this issue did not seem to be related to experience and specialization. Research (Cusworth & Dickson, 1994; Fullan, 1991; Hall & Hoard, 1987; Hargreaves, 1997a; Lovat & Smith, 1995) shows without doubt that for true, significant change in curriculum, professional development must be constantly ongoing, changing to meet the needs of the teachers and the school, and teacher driven. The traditional focus on workshops at the beginning of the implementation process is ineffective as change is a process that takes time (Englert, Tarrant, & Rozendal, 1993; Wood & Thompson, 1993). Administrators could work with groups or clusters of educators to develop programs for the reculturing of schools as in Proudford's (2003) study. This would create professional learning communities with resulting change (Fullan,1998a). Fullan (1993,1998a) and other writers (Hargreaves, 1997b; Kruse & Louis, 1995; Lieberman & Miller, 1999; McLaughlin & Talbert, 1993; Newmann & Wehlage, 1995) see the importance of reculturing schools to create professional learning communities. Newmann and Wehlage (1995) believe that "a professional community is one where teachers share common goals concerning student learning, collaboratively work together to achieve that goal, and are as a group responsible for student learning" (p. 30). Although reculturing did not occur in the schools in this study, it is suggested as a means of creating professional learning communities within and between schools for effective and efficient curriculum implementation.

The majority of the teachers felt that the principal was doing a good job, or as good a job as he/she could. Fullan & Stiegelbauer (1991) found that the more supportive the principal is of the implementation process, the more likely the change will occur. Also the majority of the teachers felt that the principal could enhance the implementation process by providing more resources.

> I think my principal is pretty supportive of us, encourages us to try, to try new things, to take risks, ... she's really encouraging, ... So other than that, its like pushing for money. (GN6)

Inservice/PD was seen as a need by four teachers. Thus inservice/PD and resources provided by the principal were seen by teachers as possible solutions to the challenges of the current curriculum. Hord et al. (1987) found that for change to occur, behaviours must be changed and teachers need help doing so. Stiegelbauer et al.(1986) found that teachers do this every time they get together with each other or with a facilitator to discuss a problem with the intent of finding a solution. Thompson, Wood & Russell (1981) believe that a personal as well as a group commitment is required to facilitate change. Teachers' discussions concerning what the principal could do to enhance the implementation process were unrelated to experience and specialization.

The study by Proudford (2003) on the restructuring of the 1-10 curriculum found that the major factors facilitating implementation were vision (clear expectations, total staff involvement), school organization (planning, guidelines), professional development and resources (Table 14). This is similar to the factors that teachers in this study felt facilitated implementation of the science curriculum. Proudford's study found that if the schools and educators worked together as a cluster, the reculturing of schools would occur. This would create "professional learning communities where teachers share common goals concerning student learning, collaboratively work together to achieve that goal, and are as a group responsible for student learning" (Newmann & Wehlage,1995, p. 30) . Figure 3 : A Framework for Building Professional Learning Communities shows the key component factors of this change process. The framework emphasizes that school cluster planning requires professional and emotional support and included in these supports there must exist curriculum leadership. Teachers from the Proudford's study felt that this reculturing of the schools "provides opportunity to use time efficiently; share workloads, expertise and resources; and gain insights into how teachers in other settings interpret and adapt the syllabuses" (p. 4).

One of the challenges teachers faced was having to discuss the curriculum with parents specifically those parents from whom they received negative feedback. Although there was very little feedback from parents, it was both positive and negative feedback. The positive feedback was received from only a few parents. These parents felt that science is important and challenging, and were impressed with the continuity and hands-on nature of the program.

> So, just the few comments that have come back to me, the parents are in some ways impressed, ...because their children are learning things that they did not learn ... (CN5)

Negative feedback was also received from only a few parents. The parents were concerned about the material being too advanced in nature for the grade 8 curriculum, and about the lack of materials needed by students to complete their activities. Teachers felt that there was little feedback from parents because the parents were already informed about the curriculum through newsletters, memos, the curriculum document, and the school council to name a few. Teachers' discussions concerning the feedback they had received from parents about the science and technology curriculum were unrelated to experience and specialization.

The Old, Present, and New Story:

The study by Miller et al. (2000) on the implementation of the Common Curriculum, examined how teachers met the challenges of curriculum implementation, alternative assessment and outcomes based learning. The results were categorized under "old story" (past practices), "present story" (present practices) and "new story". Most of the findings were categorized under present story. The findings from Miller et al.'s study and this study show many commonalities that it needs mention. In the present story of Miller et al. the vision of most of the participants did not include the traditional subject-based curriculum and paper and pencil tests, but a current vision of education which included implementing the Common Curriculum. In the present story, teachers were managing to integrate the curriculum but only to a certain extent, teachers were evaluating using rubrics, and assessing student using levels, and teachers used the outcomes as a guide for what needed to be taught and learned. Teachers collaborated in groups both formally and informally; teachers saw themselves as facilitators of learning; and, both administrators and staff were involved in the change process with administrators setting the agenda and facilitating change. Teachers valued principals and vice-principals when they were: "encouraging teachers to take risks; setting a positive tone in the school; being visible in the school and not being away from school, delegating responsibility, and communicating clearly with staff' (p. 6).

Main Concerns of Other Teachers:

The majority of teachers interviewed felt that inexperienced teachers or teachers with little or no science background would have the most concerns. The teachers interviewed felt that the other teachers question themselves about: whether their knowledge base is sufficient, their inadequate knowledge of new terminology, their need for acquiring the skills of thinking, inquiry, and problem solving, and the vast scope of the curriculum. This subsequently leads to teacher concerns about whether there is sufficient time to implement the curriculum, and the feeling by the teachers for a need for inservice to assuage these problems. The majority of the teachers saw a need for more resources in order for the science and technology curriculum to be successfully implemented. Although the teachers being interviewed expressed the same concerns, in the final analysis, their concerns were not found to be related to experience and specialization. It was felt that this question was not answered the way it was intended. The discussion here was based on the perception of the teachers. The majority of the teachers perceived that inexperienced teachers or teachers with little science background would have the most concerns. Most of the teachers did not actually ask the other teachers what their concerns were. Possible reasons for this: the teachers were not comfortable enough with the interviewer to be completely truthful, or teachers actually believed that a correlation does exist between the implementation process and experience and specialization.

In summary, teachers' discussions on the challenges the implementation of the science curriculum has posed and the solutions they have found include:

- The majority of teachers saw their role as developing an in-depth knowledge and understanding of the curriculum to assist the students to understand the curriculum and make connections, to problem solve, to think critically, to become independent learners.. The teachers felt that in order to fulfill their role, they needed to integrate the curriculum in order to cover the entire curriculum. Teachers discussed accepting the curriculum, doing the best they could, re-evaluating continually, and working collaboratively.
- The majority of the teachers felt that having a science background is necessary to teach well, and also that being qualified in science is an asset.
- Teachers' main concerns in the implementation of the curriculum included insufficient

resources to assist them to implement their lessons (teacher and student), their labs (materials, equipment and space) and their assessments and evaluations as well as the time intensive nature of the curriculum. A few teachers would like to have more inservice training.

• Although teachers found the construction of the inquiry and design method of learning challenging, the majority saw it as a positive change and felt confident in their abilities to develop the students' skills of inquiry and design as well as their questioning skills.

• The majority of teachers had both positive and negative opinions about the use of achievement levels. On the negative side teachers questioned the contradictory method and subjective nature of using levels. On the positive side teachers felt that they were easy to use and to discuss with the students.

• One teacher felt that one of the changes that had occurred in the evaluation process was the decreased accountability on the students' part given multiple opportunities to submit late work. Another teacher felt the various methods of evaluation are only considering the product, not the process.

• The assistance that teachers received from administration varied widely from a little to a lot of assistance with the principal doing as good a job as he/she could. Teachers felt that the board and the principal could enhance the implementation process by providing funds for resources (equipment, materials for a science lab, textbooks, teacher resources) and for teacher training through inservice and/or PD.

5.2 Conclusions

All teachers knew that their board expected the implementation process to take two to three years and all teachers were on schedule. In the past, all teacher had received some or all of the following: resources packages, textbooks, grant money for texts and lab equipment, attended 1-3 workshops of either ½ day to 1 day on specific units or strands and/or the inquiry method. This represents teachers' knowledge of the implementation process.

Most science teachers had a substantial knowledge of the new curriculum. Teachers were aware of the continuity, theory based, complexity and challenging nature of the curriculum and found that the advantages of the curriculum include its clarity and detail, structure, standardization, and consistency of the report card. Teachers felt that in order to cover the extensive and challenging curriculum, they need to integrate the curriculum. Teachers discussed accepting the curriculum, doing the best they could, re-evaluating continually, and looking to each other for support.

The majority of the teachers saw their roles as developing an in-depth knowledge and understanding of the curriculum in order to deliver the curriculum. Additional roles seen by the majority of teachers included the delivery of the curriculum to students in order for the students (a) to understand the curriculum, and make connections (b) to challenge the students to foster problem solving and critical thinking skills, and (c) to assist students to become independent thinkers and learners. This indicates the teacher's role is challenging and complex and involves both the understanding and the delivery of the science curriculum aiming for specific goals.

The majority (six) of the teachers felt that having a science background (general knowledge of big science ideas) or being qualified in science would assist in implementation of the new curriculum, and the findings from this study showed that most of the teachers were knowledgeable about the new curriculum, and were implementing it with little difficulty. Teachers' perceptions of their ability to teach science is a major contributor to effective science curriculum implementation.

The changes that have occurred in the means of instruction include a few broad changes with the majority of teachers allowing learning to occur in small groups, providing more opportunities for hands-on investigations, less classroom structure specifically with respect to labs, developing the students' questioning skills, and developing the students' skills of scientific inquiry and technological design, a major challenge. This major instructional challenge of developing the skills of inquiry and design was seen positively, and implemented confidently.

Teachers used a variety of assessments to analyse the skills of inquiry and design. These included assessment of group work (group presentations and labs), of independent work (labs, projects, oral), self and peer assessment, and observation.

Teachers had to make changes in their methods of evaluation. The majority (six) teachers used self and peer evaluation extensively. To evaluate the students' knowledge and understanding the majority of teachers used tests and quizzes the most frequently. Teachers also frequently assigned open-ended problems.

Although the majority of teachers had both positive and negative opinions about the use of achievement levels in their methods of assessment, science teachers were extensively using achievement levels in a variety of ways in assessing the knowledge and skills expectations through the use of rubrics in labs, assignment, projects and presentations.

One of the major inhibitors to the effective implementation of the science curriculum was lack of resources. Most teachers would like more resources to help them to implement their lessons, their labs (materials and space), and their assessments and evaluations. Most teachers' expectations for the future include more in-service/PD, teacher resources, equipment, and textbooks.

The assistance that the teachers received from administration varied widely from no to total support. The majority of the teachers felt that the principal was doing a good job, or as good a job as he could. The majority of the teachers felt that the board and the principal could enhance the implementation process by providing the funds to supply equipment and materials for a science lab, teacher and student textbook related resources, teacher training and development in the effective use of the curriculum documents in the science and technology area.

Parents were concerned about the advanced nature of the curriculum, and lack of materials, but were impressed with the continuity and hands-on nature of the program.

Thus the factors identified in this study as contributors or inhibitors to the effective implementation of the science curriculum included the time intensive and complex nature of the curriculum, the ability of the teacher to understand and deliver the curriculum with emphasis on instructional and evaluation practices, the availability of resources, administrative assistance and guidance, and the professional development provided to the teacher.

5.3 Recommendations

The science curriculum is multifaceted and demands from the student the ability to problem solve, to test their hypothesis, to use their critical thinking and inquiry skills and to communicate their findings effectively.

Teachers are aware of the scope of the science curriculum, but their comfort level would be increased by: increasing their knowledge and understanding of the content, increasing their skills in developing students' skills of scientific inquiry and technological design, increasing their skills in the use of achievement levels and by providing a sequence guideline. The providing of resources, the training and development of teachers, and the monitoring of the implementation process , and the reculturing of the schools all contribute to the success of the implementation process. In this light the following recommendations are made:

- Teachers need to work collaboratively together and integrate science with as many subjects as possible.
- More money needs to be spent/invested on the implementation of the science curriculum, with funds allocated to any required resource/equipment, and for a separate room for a science lab. The science lab is needed to provide more opportunities for the development of the skills of inquiry and design and hands-on investigations.
- There is a need for well prepared teachers. Teachers need to develop their knowledge, understanding, and skills in science as well as how to teach science. This should be a component of their professional development. Professional development should be provided on an individual as well as group basis. Teachers also need more planning time.
- There is a need to examine the assessment/evaluation practices with the aim of determining a standardized way of assessing/evaluating using levels.
- There is a need to examine ways of teaching scientific inquiry and technological design.
- Administration need to re-culture the schools to provide any assistance and guidance required for the successful implementation of the science curriculum.
- There should be a framework and support structure to ensure the continuity of the program for new and current teachers.

5.4 Suggestions for Further Research

The following studies could be done in the future for further research into the implementation process:

- Collect and analyse data from parents, administrators and teachers and students on the implementation process to find answers to what can be improved, what is needed, what stage is the implementation process, and where does it stand?
- Collect and analyse data based on the students - their attendance, attitude, concept attainment, achievement, graduation rate and other factors.
- Determine what can be done to assist students to attain the provincial standard of level three or higher and what factors are preventing students from attaining a level 3.
- Determine what can be done to make the science programs more interesting and relevant to the students' needs.
- Determine where the greatest needs for the allocation of resources occur.

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APPENDIX 1: INTERVIEW QUESTIONS

Interview 1

Name: ?

Teaching experience: Years teaching?
Years at present School?
Specialize in Science or all subjects taught?
Years teaching science?

Science Background: Under-graduate degree?
Subject Specialist?

1. Have you started to implement the new curriculum?
   Probe: Which aspects have been implemented?
   - which aspects have been given more attention?
   - which strands are you implementing and planning to ....?
   - how are you filling the remaining time (if covering only two strands)?
   - how many times per week do you see each science class?
   - how long is each period?

2. What assistance have you received from administration in the implementation of the science curriculum? - both directly and indirectly
   - textbooks - sufficient, scope of coverage of curriculum, is a variety used
   - handouts, booklets, resources, STAO
   - lab equipment
   - PD (Professional development activities)

3. What do you see to be the advantages of implementing the new curriculum?
   - compared to the old curriculum
   - better continuity
   - more structure

4. What do you see to be the disadvantages of implementing the new curriculum?
   - sufficient space/resources for labs
   - support structure
   - is there enough time to cover all aspects of the curriculum
   - your views on standardised testing

5. What changes have occurred in the content of instruction?
   - would it help to have course profiles from the board?
   - do you believe that being qualified in science is an asset?

6. What changes have occurred in the means of instruction?
   Probe: What are your feelings about your ability to develop the inquiry and design skills in your students?
   Probe: How are you fostering students' ability to construct the desired inquiry method of learning?
   Probe: How are you fostering students' ability to construct the desired technological design method of learning?
   - How are you fostering students' ability to develop their questioning skills - and is there enough time to do it all?
   - Is there more or less structure in your classroom?

7. What changes have occurred in the methods of evaluation?
   - rubrics and development of
   - self and peer evaluation
   - who should have input

8. What do you know about the implementation procedure for the new curriculum?
   Probe: What is the time frame for its implementation?
   Probe: Where is the implementation process at the present time?
   Probe: What do you know of that has been done in the past?
   Probe: What do you know of that is going to be done in the future?
   - So at the end of which school year will the science curr. be fully implemented?
   - Is this a reasonable time frame?

Interview 2

1. What professional development activities have been planned (long/short term training) to assist in the implementation of the science and technology curriculum?

2. What feedback have you received from parents about the present science and technology curriculum?

3. What do you think are the main concerns of the other teachers in the schools with respect to the implementation of the science and technology curriculum into their classroom?

4. What are your main concerns about the implementation of the science and technology curriculum?
   - is contact time between you and your students sufficient to cover all 5 strands in 10 months? Is this a realistic expectation?

5. What could the board do to enhance the implementation process?

6. What could the principal do to enhance the implementation process?

7. What do you see as your role in the implementation of the science and technology curriculum?

8. What is your opinion concerning the use of achievement levels in your methods of assessment?
   Probe: In what ways have you used the achievement levels in assessing the knowledge and skills expectations of the science and technology curriculum?

9. What types of assessments are used to judge and analyse the skills of inquiry and design?

10. What types of evaluation are used to judge and analyse the conceptual skills?

11. At this time, is there anything else that you would like to add so that others might have a better perspective of the implementation of the new elementary school science curriculum?

APPENDIX 2

Letters to School Board and Participant, Consent Form

L A K E H E A D U N I V E R S I T Y
Oliver Road, Thunder Bay, Ontario, Canada P7B 5E1
Faculty of Education

CONSENT FORM

Teachers' Perspectives on the Implementation of the Ontario Elementary School Science Curriculum

I, ________________________________ agree to participate in this research study which will examine the challenges and solutions of the implementation process with specific emphasis on the inquiry and design method of teaching science, and the methods of assessment used.

I agree to participate in two interviews, approximately 1 - 1½ hours long, and to supply the researcher with a personal log and teaching materials for a two week period.

I understand that my participation in this study is voluntary, that I may withdraw at any time, that the information given by me is confidential, and that the findings of this study will be available to me, upon request, at the completion of the study.

______________________________ ______________________

Signature of Participant **Date**

APPENDIX 3

Questions on Curriculum and Assessment Reform

Note: From *Understanding teachers' perspectives on curriculum and assessment reform or the more things change: Change-oriented, experienced teachers' views and practices regarding mandated change* (p. 24, by C. Lafleur and J. Tucker. 1997).

1. *Why do some teachers situate themselves at the leading edge of this type of change*? Are they individuals who lead our thinking and cause change? Or, are they "super followers" who make politically expedient forecasts and realize that it's better to simply get on with it?

2. *What is the change process here*? Are the teachers learning new strategies and internalizing new concepts? Or, are they simply adjusting their language to the new political milieu? What do they say when the tape is not running?

3. *How can teachers meaningfully respond to mandated curriculum changes that simultaneously promote constructivist pedagogy on the one hand and accountability demands through outcomes-based reform and measurement on the other hand*? Can we expect any coherent change processes in a political climate which demands imaginative, collaborative, transformative learning while simultaneously claiming unassailable, accountable, transmission learning? The very nature of these two different sets of mandated changes seems to promote confusion and uncertainty.

4. *How does the mandated change impact curriculum style*? Curriculum style usually refers to the "content", "process" of learning, and the "context" of learning. Given the schizophrenic nature of the Common Curriculum and the controversy surrounding the Transition Years, particularly destreaming, what is the appropriate emphasis that should be given to different curriculum styles?

5. *What is the most appropriate connection between assessment and evaluation and instruction*? While there is general openness to using a variety of assessment strategies; making the seamless link with instruction is not always an easy transition. In addition, there is a sense of mystery about how judgements of student achievement are made.

6. *Will curriculum integration ever be more than a "skin deep" change*? In the main, these teachers support the changes related to curriculum integration, but they speak the language of the traditional core disciplines of the latter 20th century. Is true integration a viable and realistic goal for all teachers?

7. *What made these particular teachers suitable for inclusion in this study*? Was it their record of curriculum leadership? their general dedication to student learning - in any context? their visibility in system work? their co-operativeness? their compliance? Given that the intent in this research was to find teachers who were involved in a serious, sustained and committed way with these curriculum reform initiatives, why were these particular teachers selected? While this may seem like a curious question to ask at this point, we

believe it has fundamental implications for the methodology of future. similar studies.

8. *Was the sample so specific that the findings are too limited?* Should the researchers have sought participants more openly. or more randomly so as to enhance the study's trustworthiness? What are the implications for similar future studies ?

9. *What is the relationship between the major themes that emerged in this study, that is, obstacles, facilitators, and beliefs and practices?* For example, subject integration and time can be both obstacles and facilitators. How are the dispositions of teachers toward educational change influenced by their beliefs and practices?

10. *Why are these teachers not working more collaboratively with others?* Are the teachers accepting only those changes that suit them and that they can handle by themselves? While there is evidence to support team teaching and co-operation with others, collaboration (in planning, staff development, organizing) was notable by its absence. Managing change seemed to be a personal responsibility.