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A FRAMEWORK FOR TEACHING
PROBLEM SOLVING SKILLS IN ENVIRONMENTAL STUDIES
AT THE JUNIOR LEVEL

by

Donna E. Ross

Thesis submitted to the School of Graduate Studies
of the University of Ottawa
in partial fulfillment of the requirements
for the degree of Doctor of Philosophy in Education

Ottawa, Canada, 1993



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ABSTRACT

The purpose of the study was to evaluate a method of instruction that promotes problem solving skills. Critics of current educational practices say that present methods of instruction are not preparing students for the requirements of the work force. While skilled in textbook procedures, student graduates lack the expertise to solve the ill-defined problems they experience and will continue to experience in a changing economic world. Experts today say that the competitive world centres around problem solving, requiring innovative thinking and technological expertise.

Skills needed to solve problems are taught in schools but in isolated "chunks" rather than being co-ordinated or integrated in an explicit problem solving approach. The implicit assumption is that students will use these skills in a problem solving context when needed. The question to be answered is, whether students would be more effective problem solvers if they were taught problem solving skills explicitly and systematically in a teaching environment which focusses on problem solving, rather than in a teaching environment which focusses on content. In a content oriented environment, the assumption is made that students will learn problem solving skills implicitly and use these skills when needed.

An adaptation of the framework of Induction proposed by cognitive scientists Holland, Holyoak, Nisbett and Thagard in their text Induction: Processes of Inference, Learning and Discovery (1986), was chosen as a theoretical base for the research. The model was chosen as it identifies three main components of problem solving: collecting information, analysing information and forming conclusions. These components were combined with the three types of knowledge also cited by cognitive scientists; declarative knowledge, knowing what; procedural knowledge, knowing how and conditional

knowledge, knowing when and where. The three types of knowledge were used to structure the questions for the data collection which consisted of four interviews over a six month period, daily learning logs and four observations in each classroom.

Sixty-four junior grade students from grades 4, 5 and 6 participated in the study. Each grade was taught the same two lesson segments, the first segment was developed for a content oriented environment and the second for a problem solving oriented environment. The objective was to identify student problem solving skills generated by the two teaching environments: one based on the Holland et al. (1986) framework of Induction in which skills, collecting information, analysing information and forming conclusions are integrated and coordinated in an explicit problem solving approach; the other, in which the same skills are developed in isolation with a focus on content.

Results showed a shift in knowledge patterns from the content environment to the problem solving environment. After being taught in the problem solving environment, student explanations to declarative and procedural knowledge questions were better structured. In addition, there was a significant increase in their application or conditional knowledge to real life situations. Also, after a four month period, there was little decline in student recall of knowledge from the problem solving environment. In fact, retention increased for some students.

The results show that the Holland et al. (1986) framework of Induction can be adapted to produce a simplified, systematic approach for curriculum design. The framework demonstrates that it can integrate the diversity and fragmentation of skills being recommended in curriculum guidelines and resource books.

CHAPTER ONE

INTRODUCTION

One of the thirteen goals of education for the Province of Ontario states that students will acquire skills and attitudes that will lead to satisfaction and productivity in the world of work. However, articles in professional journals (Crane, 1992; Smith, 1985; Steier, 1989) suggest that graduating students have difficulty using acquired knowledge in dealing with complex ill-defined issues in the workplace. They have superior technical knowledge but are not able to use it in real life situations. Have skills learned in school taught students to be productive thinkers or problem solvers?

Skills needed to solve problems are taught in schools but in isolated "chunks" rather than being coordinated or integrated in an explicit problem solving approach. The implicit assumption is that students will use these skills in a problem solving context when needed. Examples of resources providing many ideas for skills development but not following an explicit problem solving approach are: Ages 9 through 12, A Resource Book for Teachers (1986), Curriculum Inserts in the monthly publications of the Ontario Federation of Women Teachers' Associations of Ontario (1990) and Ontario Science Centre, Science is Happening Here (1988). The question to be answered is whether students would be more effective problem solvers, if skills were explicitly and systematically taught in a problem solving environment, rather than in a content oriented environment where skills are developed according to the implicit assumption that students will use these skills in a problem solving context, when needed.

Asian countries are revitalizing their educational practices and demonstrating that expertise in problem solving can develop quickly (Crane, 1992). Cushman (1992) reviews approaches used in the teaching of mathematics in Asian and American classrooms which have been studied to determine why Asian children are consistently superior to American children in their test results. The Asian lessons began with the teacher presenting a concrete real-life problem, to which the students developed possible approaches to solve the problem working alone or in groups. Next, students shared approaches of solving the problem making sure they were able to defend their approach. In contrast, the American lesson covered more problems but treated them in a way that required minimal demands on reasoning. The lesson usually began with the teacher giving an explanation of a procedure. Then the students were given assignments in which they used the procedure just explained. Voss, Perkins and Segal (1991) claim that in Japanese classrooms, mathematics problems serve different instructional purposes than in American classrooms. In Japanese classrooms, the lessons provide opportunities for promoting proficiency in mathematical reasoning, whereas in American classrooms, these lessons provide opportunities for promoting fluency in the execution of mathematical procedures.

Schoenfeld (1991), in his criticism of American mathematics teaching, says that we must make sense out of our teaching. Citing several studies, he argues that curriculum delivered by teachers in the ways sanctioned by schools is divorced from life. Students are trained to see mathematics in ways which bury reasoning. Teachers give you rules which are memorized and then used in problems. Applebee (1991), studied the nature of school writing assignments. He found that in most classrooms writing represents an opportunity to assess factual knowledge rather than an opportunity to assess reasoning skills. In the John Dewey lecture at the American Educational Research Association Meeting, Schoen (1990), states that schools, over the years have been institutions of knowledge and have

paid little attention to the practical problems of everyday life. Voss et al. (1991), in reference to current studies on educational reform, suggest that problem solving is more important today than ever before. They say that we live in a highly complex and rapidly changing technological environment with the workplace demanding a high level of reasoning. And, trend data indicates that the workforce can expect to encounter more challenging reasoning requirements than today. Occupations requiring a high level of reasoning are increasing, whereas occupations requiring a low level of reasoning are declining. Thus Voss et al. (1991), conclude that the present role of educators to teach problem solving is clearly defined.

Bellanca and Fogarty (1992), reference the many problem solving models that have been introduced to educators. However, the literature suggests that few teachers have incorporated these problem solving models into their daily lessons (Greeno, 1991; Swartz & Perkins, 1989; Schoenfeld, 1991). According to Quellmalz (1987), interpretation of so many models with varying terminology is confusing and thus difficult to apply. The lack of use of the Process Scope and Sequence Manual (1988), published by the Carleton Board of Education, provides further support for a simplified framework. The manual identified various thinking skills to be used with existing content requirements in order to teach problem solving skills. Teachers reported it too complex and fragmented to understand. Consequently, there is a need to identify a simplified framework of thinking and reasoning skills which can relate to all subject domains.

The field of cognitive science has proposed unified frameworks for human thought processing or problem solving. The present study selects such a framework, and applies it to an educational setting. Skill development is identified in two teaching environments: an environment with an emphasis on teaching problem solving and an environment where the

emphasis is on the teaching of content. The implicit assumption is that these skills will be used appropriately in problem solving when needed. Thus, the objective of the proposed study may be stated as:

- to identify student problem solving skills, after the students have been taught in two different teaching environments: one, in which skills are integrated and coordinated in an explicit problem solving approach; the other, in which skills are developed in isolation with a focus on content.

The next chapter, Review of the Literature, first provides relevant information in the development of problem solving approaches. Frequently cited terms in problem solving, critical and creative thinking are clarified. Their mutually supportive role in present problem solving theories is described. The importance of integrating problem solving with curriculum content is proposed followed by techniques for integration. Next, teaching for transfer and the role of metacognition are reported. The conceptual framework is then described and justified followed by a statement of the research objectives.

The Methodology chapter outlines how the study was conducted. Data were collected sequentially, first, when working in a content oriented environment and second, when working in a problem solving oriented environment.

The Results chapter identifies the patterns observed in the two different teaching environments. Interpretations for such patterns are provided in light of the theoretical framework and, in reference to the studies cited in the Review of the Literature chapter.

Using the patterns from the Results chapter, the Discussion provides suggestions for curriculum design and implementation. The chapter concludes with possibilities for future research along with the limitations and educational implications of the study.

CHAPTER TWO

REVIEW OF THE LITERATURE

Development of Problem Solving Theories

The psychology of human thought has given rise to many theories throughout time. Of particular interest in the development of current problem solving research is the work of the Structuralists, the Behaviorists, and the Gestaltists. A review of the historical writings of Boring (1950) and Dellarosa (1988) elicits the following significant information.

Beginning with the structuralist view of the late nineteenth century, thought was explained in physical terms. The Structuralists believed that thinking was entirely a physical process and their research focussed on the identification of the physical sensations that underlie everyday experiences. However, the work of the Behaviorists, especially Pavlov in stimulus substitution, showed that learning could be described in terms of the associations among external stimuli and responses. In contrast to the Structuralists, they believed that environmental influences were the sole determinants of behavior and overt behavior could be the only legitimate focus for scientific study. Continuing from the structuralist framework, another school of thought emerging at the same time, was Gestalt psychology. In contrast to the Behaviorists, they believed that a whole perception within the mind could not be understood by an external analysis of its parts. The wholeness of a perception was a part of an internal cognitive system. In an attempt to understand the processing of this internal cognitive system Duncker, a Gestalt psychologist, studied subjects

solving problems. He required them to "think aloud" as they moved through the problem solving process. He found that the problem solving process required an analysis of the differences or conflicts between the goal and current situations and an analysis of the means to reduce those differences. The outcome of this process was a collection of highly integrated internal representations. Thus, Duncker's work contrasted sharply to the behaviorist view which relied on trial and error learning. But an integration of views related to human thought processing and environmental considerations emerged later with the collaborative work of psychologists, philosophers, computer scientists and neuro scientists in the field of cognitive science. The role of cognitive science will be reviewed later in the chapter.

Not only were groups of psychologists searching for explanations of human thought, but at the same time academics were supporting a pragmatic view of problem solving stressing the relation between mental events and action. In America, Dewey (1933), a recognized pioneer in problem solving, viewed all thinking as problem solving. He felt that thought could not be understood without action, with the individual being confronted with a problematic situation and thus directed toward a conscious goal. Dewey referred to steps: suggestion, formation of a problem, hypothesis, reasoning and testing of hypothesis. Dewey's philosophy has been a legacy for others, evidenced by the fifty year old John Dewey Society, a group which continues to promote his work. In Russia, the translations of Vygotsky (1978) showed that he viewed the learner as an active investigator of the environment rather than a passive recipient of information. Social contact was an important factor as one interacted with others, especially those with more expertise. Vygotsky referred to the "zone of proximal development". The zone of proximal development was the distance between a child's actual developmental level as determined by independent

problem solving and the higher level as determined through problem solving under adult guidance or in collaboration with more capable peers. In Europe, Piaget (1972), although not emphasizing social interaction, stated that when the learner is faced with a problem an interaction takes place between the learner's existing cognitive structure and the environmental situation in question. Moving through various stages of cognitive development from pre-operational, to concrete and finally to abstract thought the learner incorporates and accepts new experiences within their present internalized frame of reference. In summary there was a movement throughout the world to view problem solving as the interaction of the mind with the environment.

Based mainly on the work of Dewey (1933), other problem solving models emerged. However, the events of the Second World War had a particular impact on the design of problem solving models. After the War, Guilford (1967), a member of the American armed services, stressed the need to find new and creative ways to solve the problem of establishing world peace. The distinction that Guilford made between divergent and convergent thinking in his Structure of the Intellect Model has been widely recognized and used since then as the basis for designing many problem solving models. Divergent thinking emphasized the creation of new ideas, whereas convergent thinking emphasized analysis and reason. McPherson (1977), in an attempt to clarify terminology amongst problem solving models that had been developed up to the 1960's, identified three common types of thinking found in the eighteen problem solving models that he referenced. They were creative, analytical and judicial thinking.

Because of the increased emphasis on creative thinking, problem solving models were introduced which focussed heavily on divergent thinking. Osborn (1953), developed a three stage problem solving model; fact finding, idea finding and solution finding. Within each step, he designed many techniques to teach the use of creative thinking such as brainstorming and deferred judgment. Brainstorming is the generation of many ideas without discrediting any at the onset. Deferred judgment means that no decisions related to the task are made initially, in order to allow for time to think about the possibility of enhancing or refining any ideas. Parnes (1967), enhanced the Osborn model, but after implementation realized that an unleashed imagination without judgment was ineffective. Because judgment and logic had been emphasized in earlier models to the exclusion of imagination in the past, Osborn (1953) and Parnes (1967), had concentrated almost solely on models designed to stretch the imagination. Now the need to strengthen the imagination and judicial abilities concurrently, was recognized because the more imagination a person calls forth, the more potential consequences, repercussions and effects can be seen of ideas that might be put into action. Hence, Parnes (1972) and Parnes, Noller and Biondi (1977), spoke of a dynamic balance between creative and critical thinking. However, no specific ways were outlined at that time on how to balance creative and critical thinking when moving through the problem solving process.

Definitions of Creative and Critical Thinking

At this point the terms creative and critical thinking were being used and interpreted in many ways. What follows is a clarification of terminology and the current status of creative and critical thinking in problem solving models.

Based on Guilford's Structure of the Intellect Model (1967) many studies have been conducted over the years in order to understand creative thinking (Torrance 1962, 1972, 1974, 1979; Torrance & Hall, 1980). Torrance (1974), proposed the divergent thinking components of fluency, flexibility, originality and elaboration. His work has provided the rationale and impetus to continue to develop techniques to teach these components of creative thinking. Torrance and Myers (1970), defined creative thinking as becoming sensitive to problems, deficiencies, gaps in knowledge, missing elements, disharmonies, identifying the difficult, searching for solutions, making guesses or formulating hypotheses about the deficiencies, testing and retesting these hypotheses and possibly modifying and retesting them; and finally communicating the results.

Treffinger (1987), defines creative thinking as a process of generating ideas which may emphasize fluency, flexibility, originality and elaboration. In addition, he defines critical thinking as the process of analysing, refining, developing or selecting ideas, including categorizing, comparing and contrasting, examining arguments and assumptions, reacting and evaluating inferences and deductions, setting priorities and making choices or decisions.

Currently, some theorists are integrating the concepts of creative and critical thinking in their definitions. Ennis (1985, 1987), defines critical thinking as reasonable reflective thinking that is focussed on deciding what to believe or do, noting that the definition does not exclude creative thinking. According to Ennis, formulating hypotheses, alternative ways of viewing a problem, questions, possible solutions, and plans for investigating something are creative acts and come under his definition of critical thinking. Perkins (1985, 1988), in his concept of creative

thinking refers to creative thinking as thinking in a planned or patterned way that leads to creative results. He stresses the importance of action or output based on making a decision, formulating a hypothesis or reaching a conclusion: all critical thinking or convergent acts.

Marzano et al. (1988) discuss the teaching of critical and creative thinking concurrently rather than separately in order to stress that they are complementary and that both are necessary to attain any worthy goal. Whenever students are formulating a question, analyzing a text, or defining a term with clarity, accuracy, and fair mindedness, they are developing skills of critical thinking. Whenever they solve an unstructured problem or plan a project they are developing their creative abilities. Whenever they consider diverse points of view and imaginatively, empathically and accurately reconstruct them, they are thinking both creatively and critically.

Mutually Supportive Roles of Creative and Critical Thinking

The literature on creative and critical thinking supports the integration of both types of thinking in defining a concept of thinking. What is important to highlight now is the development of problem solving models that focus on the integration of both types of thinking.

Isaksen and Treffinger (1985), influenced mainly by the work of Parnes (1967) and Parnes, Noller and Biondi (1977), specifically began to outline ways of using both creative and critical thinking techniques in their Creative Problem Solving Program. Creative Problem Solving is defined as a six stage process for using specific techniques of creative and critical thinking which are in harmony, not in

opposition to solving a problem. The stages are Mess Finding, Data Finding, Problem Finding, Idea Finding, Solution Finding and Acceptance Finding. At each stage, techniques are used to find creative ways to deal with the task. Then techniques are introduced to make a critical decision about which way is most appropriate.

Another recent model is the IDEAL problem solver (Bransford, Sherwood, & Sturdevant, 1987; Bransford & Stein, 1992). The IDEAL problem solver emphasizes five components of thinking that are applicable to a wide variety of situations. These include the ability to identify problems, define and represent them with precision, explore possible strategies, act on these strategies and look at the effects. Creative thinking is an integral part of what they call the IDEAL cycle. For example, the problem solver is encouraged to define, explore strategies, evaluate and then possibly look at the problem in another way. In accord with deBono (1986), they suggest that an important aspect of creative problem solving is whether faulty assumptions are being made about the nature of a problem that limit the ability to find solutions. In summary, creative and critical thinking are integral components of problem solving models being developed today. The two models referenced have a wide variety of uses and are recommended for use in schools. A question which arises is whether models such as Creative Problem Solving and the IDEAL problem solver should be taught in a separate curriculum or infused with the regular program.

Whether in a separate or infused program, the recognition that creative and critical thinking skills should be taught is evidenced by the number of thinking skills programs

available today. Bellanca and Fogarty (1992), identify twenty-nine different types of programs, all aimed at the need to teach thinking skills. Included in the programs are Creative Problem Solving and the IDEAL problem solver. The programs may be taught as a separate curriculum or infused into the existing curricula. Sternberg (1987), cites the advantages of both. The separate programs are less likely to be overpowered by knowledge-based curriculum and allow students to get a clear sense of just what the thinking skills are and the skills can be evaluated outside of the content areas. Infused programs on the otherhand, do not require a wholly separate course which may not fit into school priorities. They seem to run less risk of the knowledge learned never being applied outside the thinking skills classroom. Also, they reinforce the thinking skills throughout the curriculum rather than conveying the message that thinking skills are something apart from the curriculum. Costa (1991), cites research that favours the approach of infusing thinking skills into the regular curriculum, saying that the ability to perform certain cognitive processes is basic to success in school subjects. Hierarchical thinking, for example when taught prior to or along with the skill of outlining, produces better results than if taught without that cognitive prerequisite. In addition, Perkins and Swartz (1992), support the integration of thinking skills within the curriculum.

Integration of Problem Solving with Curriculum Content

The integration of thinking skills with curriculum content is introduced by Eggen, Kauchak and Harder (1979) in their text, Strategies for teachers: information processing models in the classroom. Outlining the importance of goal oriented instruction they state:

1. All the information we get about our world is gathered through the process of observation, whether it be directly through the senses or vicariously through written words and symbols.
2. Observations are explained, organized, and interpreted through the process of inference which is an extension of the process of observation. As such, the two processes are interdependent, and both are essential in helping to make the world around us comprehensible.
3. We can always be more confident of the validity or accuracy of our observations than we can of our inferences.
4. The ability to make accurate inferences or to judge the accuracy of others' inferences does not come naturally. It is a skill that requires practice. A goal for teachers should be to teach students to make inferences based on observations, to recognize differences in the validity of inferences, and to avoid inferring (generalizing) on the basis of inadequate observations. Acquiring such an ability often means the difference between clear and fuzzy thinking (p. 28).

In citing the similarities of teaching models, Eggen et al. (1979), state that they all have a problem to be solved, hypotheses are formed, data are gathered, hypotheses are analysed in terms of the data, and a conclusion is reached. Most important to note is that they are organizational mechanisms for large bodies of content with the primary differences being the content demands on the learner. All models provide techniques for developing process skills, that is making observations and inferences as well as promoting content learning. Thus, the teacher using the models is able to teach content and process as interrelated and complementary, promoting both the development of thinking skills and the acquisition of content. In summarizing the components of information processing models, Eggen et al. (1979) refer to the ways in which people deal with stimuli from the

environment by collecting information, analysing the information and then finding a solution.

More recently, Glaser and Pellegrino (1987) have conducted studies which demonstrate the integration of content with problem solving for instruction. Their research has been predicated on the assumption that aptitude tests should be viewed as more than predictors of achievement. Such tests should assist in identifying the processes involved in intellectual competence. In addition, they are attempting to show how these processes can be used in instructional design. While the research is in its early stages, their findings show three important components necessary for aptitude for learning. They are; management of memory, knowledge representation and problem solving procedures. The skilled individual possesses knowledge of both the content involved in a problem and the processes needed to solve the problem. Thus, their findings lead to the suggestion that the improvement of the skills of learning will take place through the exercise and development of procedural problem solving knowledge. Learning skills are developed when students are taught more than the mechanisms of recall and recognition for a body of knowledge. Learning skill is acquired as the content and concepts of a knowledge domain are attained in learning situations that constrain that knowledge in the service of certain purposes and goals. The goals are defined by uses of that knowledge in procedural schemes.

Techniques for Integrating Problem Solving and Content

While the integration of thinking skills with curriculum content is being recommended, research on the techniques used in combining content with problem solving should not be neglected.

Bransford, Vye, Kinzer and Risko (1992) show that the evidence is overwhelming that people's ability to think and solve problems is affected considerably by the nature and organization of the knowledge they have already acquired. Factual information is likely to be called into service only if it is understood and stored within well-structured, well-elaborated networks that render ideas memorable in situations where they will be needed. Anderson (1983) and Gagne (1985), postulated that learning of new knowledge takes place when new ideas become linked to prior knowledge in an existing propositional network. They suggested that the connection between new and old ideas is most likely to take place within the small attentional area called working memory. Working memory has two functions. One function is to process new information to be learned and the other function is to connect the new information to ideas that have been retrieved from long term memory. Teachers must realize that in this conscious thinking area, in which much of our formal learning occurs, only a few ideas can be held at a time. Therefore, knowledge to be retained must be introduced in small segments. Recall of needed information is greatly aided when a student's idea network is organized (Derry, 1990; Hunter, 1992).

Perkins (1987), explains a theory of knowledge for teaching thinking. He stresses what constitutes knowledge rather than what people do to think well. He feels that such an approach lays a good foundation for any method that aims to integrate the teaching of thinking with content instruction, because content deals with the knowledge and know how of particular fields. Understanding any piece of knowledge requires being able to answer four design questions. They are; what is its purpose, what is its structure, what are model cases and what arguments explain and evaluate the object? Perkins (1987), makes reference to simple objects such as a thumbtack for clarification. However, what is

important to note in Perkins' work is a sensitivity to the combination of thinking and content skills instruction.

In addition, Reif and associates have conducted several studies which show how to teach content and problem solving. Eylon and Reif (1984) found that learning tasks must be explicit and knowledge must be organized systematically and correctly incorporated into a problem solving model. They state that most conventional teaching is fairly implicit. It relies predominantly on presenting information, giving examples and providing opportunities for practice, assuming that students will somehow learn from these experiences. But they point out that studies have revealed that many of the underlying thinking skills are quite complex. Such complex thinking skills are learned rather ineffectively or inefficiently by such implicit teaching methods. Heller and Reif (1982), validated a model to teach problem solving skills in mechanics. From their work they concluded that problem solving skills are not learned from mere examples and practice. A potentially more effective instructional method teaches problem solving skills with essential components identified and these components taught explicitly. Then all these components are integrated to achieve effective problem solving. First, they stress the importance of domain specific knowledge needed to solve the problem. This knowledge must be taught in a hierarchy and described at various levels of detail. Then with clear guidelines this knowledge is applied to a problem. They subdivide the problem solving process into three major stages: the generation and analysis of the initial problem, the generation of the actual solution and the assessment of the solution.

Miller (1988) advocates a holistic curriculum which encourages relationships or a connectedness of subjects, intuitive and linear thinking, mind and body and the individual

and the community. Miller (1988) suggests the Isaksen and Treffinger (1985) Creative Problem Solving approach as one means of integrating subject matter and thinking.

Teaching for Transfer

While the importance of teaching thinking processes along with content has been demonstrated, another component must be taught. Heller (1983), stresses that knowledge of when to perform procedures is extremely important, and must be made explicit to students along with what they must know and how to perform the tasks. Reif (1987), in a final report which summarizes the work he and his colleagues have done to test instructional design, states that a basic criterion for ultimately desired intellectual performance is that a person's knowledge should be effectively usable. Knowledge should be applicable in a wide range of situations. He cautions that while knowledge can be presented sequentially or locally organized by topics, students must be given help to integrate their accumulating knowledge in a coherent structure facilitating flexible use.

Chi (1987), in recognizing the need to teach for transfer, stresses the importance of goal identification during instruction. If students have not properly encoded the goal, then in another situation they will not know how to reactivate the procedure or problem solving process within their cognitive processing system. In support of Chi, Perkins (1988), states that problem based teaching facilitates transfer. However, according to Perkins and Salomon (1988), transfer does not occur unless it is taught. They refer to two teaching techniques, hugging and bridging. Hugging means the reference by the teacher to other situations which are similar to the problem situation that has been taught. With bridging, the teacher identifies the general principle behind the concept taught and then challenges the students to apply the principle to other situations.

In order to facilitate flexible use of learned knowledge Bransford et al. (1992) introduce the concept of Anchored Instruction. Anchored Instruction emphasizes problem oriented experiences in which a multi-disciplinary perspective is taken on a single problem area and thinking is sustained about the problem. In addition to content knowledge and knowing how to do the problem, the approach emphasizes conditionalized learning. Knowing when to use acquired information is an extremely important aspect of learning which involves knowledge about the conditions under which it is applicable. Without knowledge of these conditions, knowledge cannot be applied. Greeno (1990), refers to situated learning, information must be introduced in situations where the problem may occur. Holyoak (1990), says for transfer to occur, the data must be sufficiently abstract that identification with the problem is not just in one particular situation. Transfer occurs if the superstructure is abstract enough to encompass the old and the new problem situation. Transfer of knowledge has been identified by Schoenfeld (1991) as important in mathematical problem solving and teachers must teach for transfer. And in accord with Reif (1987), knowledge should be effectively usable so that it can be applied correctly and flexibly in a wide range of situations.

The caption on the front cover of an Educational Leadership Issue, (Brandt, Ed., 1993) is Authentic Learning. An article within the journal by Newmann and Wehlage identifies three criteria for authentic learning to occur. First, students must be able to construct meaning from their acquired knowledge. Second, they must use disciplined inquiry and third, their work must be aimed at performances and products that have meaning beyond school. Brandt, in the overview titled, More Like Life Outside, highlights problem based learning as the key to authentic learning.

Metacognition and Problem Solving

Knowledge of what information is needed, how and when to use it to solve problems requires conscious thought or reflection as termed by Dewey (1933). Dewey used the term reflective thinking in conjunction with problem solving. He described the process of teaching intended to develop the progressive states of what he called "reflective thinking". These states are, suggestion, formation of a problem, hypothesis, reasoning, and testing of the hypothesis. When students engage in reflective thinking they must utilize and process data to test the answers they have given to problems.

Flavell (1976), refers to this conscious or active engagement of the human mind as metacognition. He defines metacognition as the monitoring and consequent regulation and orchestration of one's cognitive processes toward some concrete goal or objective. Sternberg (1987), in his triarchic theory of intelligence, cites the importance of executive processes, metacomponents, which consist of the planning, monitoring and evaluating of one's strategy for solving problems. Included also in his theory are knowledge-acquisition components and performance components which deal with the knowledge and skills needed to solve the problem. Marzano et al. (1988), in their concept of metacognition, outline two aspects in knowledge and control of process, one aspect being the executive control of behavior. Executive control of behavior includes evaluation, planning and regulation of one's behavior as the problem is being solved. More specifically, planning, monitoring and evaluating the learning activity are the components of metacognitive processing. Students become aware of their own thinking and what goes on inside their heads when they are thinking prior to, during and after a learning activity. In the current writings about metacognition, Swartz and Perkins (1989), gauge the sophistication of thinking by four distinctive levels that are increasingly metacognitive in nature: (a) tactic

use, doing a kind of thinking without thinking about it, (b) aware use, conscious of when one is doing a certain kind of thinking, (c) strategic use, organized thinking by conscious strategy and (d) reflective use, reflecting upon thinking before, during, and after the process, pondering how to proceed and how to improve.

Besides executive control of behavior, the other aspect in knowledge and control of process cited by Marzano et al.(1988) is one's awareness of three types of knowledge: declarative, procedural and conditional. Declarative knowledge is the knowledge of factual information needed to perform the task. Procedural knowledge is the knowledge of how to perform the task. Conditional knowledge refers to when and which procedure to use. According to Marzano et al. (1988), awareness of these three types of knowledge is essential in the development of metacognitive skills and teachers should systematically teach and reinforce them. In support of Marzano et al. (1988), others stressing the importance of teaching metacognitive skills to students are Mousseau (1989), Nandi (1990) and Swartz and Perkins (1989).

In order to integrate cognitive and metacognitive skills, Chi (1987) proposes a framework to represent what she calls knowledge and metaknowledge. She use the terms declarative and procedural knowledge to identify the components of knowledge and metaknowledge. Recognizing the need for clearer definitions of cognitive and metacognitive knowledge, she emphasizes the importance of the integration of all types of knowledge in cognitive research.

Important to the present study is the definition of metacognition proposed by Paris and Winograd (1990). They argue that students are displaying metacognitive skill if they can verbalize their declarative, procedural and conditional knowledge in relation to a

problem. Note the construct of metacognition has been limited to knowledge about cognitive states and abilities that can be shared among people by verbalization. Accordingly, valuable insights into a person's thinking can be documented and thus interpreted or understood.

Quellmalz (1987) and Sternberg (1987), stress that there is a need to merge models and attempt to identify a core of thinking and reasoning skills common to theory and research. School systems need to launch systematic programs that combine a coherent framework of skills with sound instruction. Referencing the work of current philosophers and psychologists, Quellmalz (1987) proposes a manageable framework of common skills to lessen the confusion in the use of terminology. The skills suggested in the proposed framework are those of analysis, comparison, inference and evaluation, and are referred to as core skills, which according to Quellmalz (1987), are a reasonable starting point for developing a coordinated program of instruction. In providing specific examples of lesson plans to support the framework, Quellmalz (1987) uses headings: read/gather information, analyse/interpret and write/revise. Note the similarity to collecting information, analysing information and forming conclusions, which are components of problem solving models cited by Eggen et al. (1979).

Contributions of Cognitive Science to Problem Solving

The need to find a common framework that explains human problem solving is being addressed in cognitive science, a field which integrates work of computer scientists, philosophers, psychologists, neuroscientists and educators. Computer science has made a major contribution to the field by the development of simulation models or computer programs that model human thought processing. To date four major frameworks of

cognition have been identified. They are ACT (Anderson, 1983), SOAR (Laird, Newell & Rosenbloom, 1987), PDP, Parallel Distributed Processing (Rumelhart, McClelland and the PDP Research Group, 1986) and Induction (Holland, Holyoak, Nisbett and Thagard, 1986). It should be noted that, throughout the paper, the term "Induction" refers only to the framework proposed by Holland et al.(1986). The word induction is used in many ways, especially in education, so in order to avoid any confusion in terminology it will be reserved for the context of the Holland et. al. (1986) framework.

All four frameworks follow a problem solving approach to human thought processing. Induction has been chosen as the theoretical base for the study for four reasons. First, it has been shown to have a wider range of applicability. The others have been used mainly in science, whereas Induction has been used in science, language and the social sciences. Second, the importance of learning from experience is unique to Induction. In accord with Farnham-Diggory (1972), Piaget (1972) and Vygotsky (1978), the learner is viewed as an active investigator of the environment. Problems are solved by an interaction between existing knowledge and the environmental situation in question. Third, the Holland et al. (1986) framework of Induction emphasizes the importance of flexible thinking. They say that through the recategorization of rules or the use of analogy alternative approaches to solving a problem may be developed. Educators have shown that continued, flexible recategorization of information is important in order to permit alternative ways of looking at the given situation (Osborn, 1953; Stanish 1979, 1988). Fourth, Induction recognizes the variability of the environment allowing for ways to integrate previous problem solving processes with possible new approaches. Thus, it incorporates transfer of knowledge into the framework.

Three components of problem solving have been identified throughout the Review of the Literature; collecting information, analysing information and forming conclusions (Bransford & Stein, 1992; Eggen et al., 1979; Isaksen & Treffinger, 1985; McPherson, 1977). Yet cognitive scientists use terms, declarative knowledge, procedural knowledge and conditional knowledge, to explain problem solving processes (Anderson, 1983; Laird et al., 1987; Lesgold, 1988; Rumelhart et al., 1986 and Holland et al., 1986). Recall declarative knowledge is the knowledge of factual information needed to perform the task. Procedural knowledge is the knowledge of how to perform the task. Conditional or contextual knowledge is to know when and which procedure to use. In addition, Chi (1987), Marzano et al. (1988) and Paris and Winograd (1990) use the terms declarative, procedural and conditional knowledge to explain metacognitive processing.

Most important, experts in all three fields, problem solving, cognitive science and metacognition share a common goal of seeking to find how individuals process information. If theorists in problem solving are using one set of terms for explanation and experts in cognitive science and metacognition are using another set of terms, it is important to understand the relationship between terminology. What follows is an explanation of the terms used in the Holland et al. (1986) framework of Induction; declarative, procedural and conditional knowledge and how they relate to the terms used in problem solving models; collecting information, analysing information and forming conclusions. The headings from the problem solving models will provide the structure for the explanation.

Collecting information relates to factual knowledge or declarative knowledge, knowing what. A problem solver has to have collected facts necessary for solving the problem before solving it. Declarative knowledge is represented in terms of propositional networks. These networks of meaningful units of information are stored in such a way to

facilitate retrieval. These units are sometimes called chunks, scripts, frames or schema, but in Induction, Holland et al.(1986) refer to rules which combine to form mental models. They wish to allow for more flexibility in retrieval, saying that sometimes an exact chunk of information is not sufficiently relevant to the task at hand. And, what is happening outside the cognitive system, the environment, must be considered also. Hence they refer to synchronic and diachronic rules. Synchronic rules are formed by associations and categorizations with other established rules in the cognitive system. Diachronic rules are developed through ongoing learning experiences in everyday life. Both sets of rules, synchronic and diachronic, compete with existing rules in the framework for a position in a hierarchy. In this hierarchy, rules which are supportive of each other are categorized to form a mental model. The rules provide a set of expectations that are coherent as long as they are not contradicted by more specific information. New rules can be formed depending on the success or failure of the current situation. Thus rule formation is an ongoing, flexible, recategorization of the environment and cognitive system from which mental models are formed. The flexibility is attributed mainly to the use of analogy for the integration of rules and mental models in the framework. An explanation of analogy follows.

Analogy is a way to generate new rules applicable to a novel target problem by transferring knowledge from a source domain that is better understood. Thus analogy serves as a way to transfer information from one mental model to another. There are many problem solving contexts from which analogies can be used, showing the wide range of applicability for the Holland et al. (1986) framework. In law, analogy is used to demonstrate the applicability of a statute to a new situation. An example in mathematics is the use of analogy to signify proportion or equality of ratio. Many of the most brilliant discoveries in natural science have been the result of a discovery of a relationship between a

known and an unknown entity such as the discovery of insulin, penicillin and radium. In art, Edwards (1986) shows how visual representations can be made of inner thoughts. Subjects drawing emotions such as joy, anger and fear have demonstrated similar structural representations. Edwards terms the representations, analog drawings, and has shown that the inner world of an individual can be made visible through the use of analogy in art. The most prevalent use of analogy in language is the metaphor. Many techniques have been developed to help people use metaphors (Gordon, 1961; Stanish & Singletary, 1987) and these techniques are used extensively to develop creative thinking.

Thus, the memory network contains declarative knowledge, knowing what. However, the student must also know procedural knowledge. Procedural knowledge is the knowledge needed for analysing information and carrying out the steps to solve the problem.

Analysing information is the term consistently used in the problem solving models to explain the processes used to solve a problem. Knowledge of how to solve the problem has been defined by Marzano et al. (1988) as procedural knowledge. According to Glaser and Pellegrino (1987) the skilled individual possesses not only the factual knowledge to solve the problem but procedural problem solving knowledge. Procedural knowledge, according to Holland et al. (1986), is represented by condition-action rules. If such and such a condition is present then such and such an action will occur. These condition-actions are called productions and a set of productions is called a production system. The condition side of a production rule takes as argument the structure of the declarative knowledge and the production itself constitutes procedural knowledge that either modifies or adds to the cognitive structure.

The four frameworks, ACT (Anderson, 1983), SOAR (Laird, Newell & Rosenbloom, 1987), PDP, Parallel Distributed Processing (Rumelhart, McClelland and the PDP Research Group, 1986) and Induction (Holland, Holyoak, Nisbett and Thagard, 1986) refer to means-ends analysis to solve a problem. Using means ends analysis, the problem solver attempts to solve a sub problem, then another until a solution is found. However, Holland et al. (1986) say that means-ends analysis is insufficient for solving ill-defined problems. They state that rather than simply applying operators to a fixed problem representation, the representation itself may be transformed. The transformation can occur by recategorizing the problem components by other associations. Such restructuring implies that search takes place beyond the space identified in the means-analysis approach. This type of processing depends on the simultaneous activation of multiple pieces of knowledge that both compete with and complement each other in revising the problem representation. Because many productions occur simultaneously allowing for more transformations, the Holland et al. (1986) framework permits more flexibility in thought processing. If successful, the problem solver applying procedural knowledge solves the problem.

However, the restructuring needed to solve the problem cited by Holland et al. (1986) gives rise to another type of knowledge: conditional knowledge or knowing when to use a skill. In order to form the appropriate conclusions, Holland et al. (1986) propose that a cognitive system can direct its thought processes according to its current problem situation. Holland et al. (1986) refer to triggering conditions to activate the cognitive system to respond to the situation at hand. Rules are generated that are likely to be useful at the moment and hence possibly useful in the future as well. They stress the importance of the variability of the environment stating that the cognitive system is guided by prior knowledge about the variability of classes of objects and events. In other words, the

cognitive system has the ability to deal with the everchanging events or the uncertainties of everyday life that confront the individual.

Relationship of Induction to Educational Research

In summary, the framework of Induction relates to the work of educational researchers in the following ways:

1. The Holland et al. (1986) framework outlines an integrated problem solving approach which includes data collection skills, analysis skills and skills to form conclusions. Models of instruction as outlined by Eggen et al. (1979) suggest a similar integrated approach. A systematic plan of action is inherent in such an approach which is supported also by the work of Eylon and Reif (1984) and Swartz and Perkins (1989). These authors emphasize that the teaching of knowledge and skill acquisition be done explicitly, an important way being the building of hierarchial structures of knowledge. In addition, Ennis (1987) and Sternberg (1987), cite the importance of organizing knowledge using structures appropriate for generating conclusions.
2. The Holland et al. (1986) framework of Induction stresses the importance of learning from experience. In accord with Farnham-Diggory (1972), Piaget (1972) and Vygotsky (1978), the learner is viewed as an active investigator of the environment. Problems are solved based on an interaction between existing knowledge and the environmental situation in question.
3. The Holland et al. (1986) framework of Induction emphasizes the importance of flexible thinking. Through the recategorization of rules or the use of analogy alternative approaches may be developed. Educators have shown that continued, flexible recategorization of

information is important in order to permit alternative ways of looking at the given situation (Osborn, 1953; Stanish 1979, 1988).

4. The Holland et al. (1986) framework considers the variability of the environment and provides an explanation of how skills are transferred to solve ill-defined problems. The need to prepare students to solve these ill-defined problems in the workplace has been identified by many such as Bransford et al. (1992), Chi (1987), Reif (1987), Perkins (1988), Smith (1985) and Steier (1989).

5. The Holland et al. (1986) framework has been shown to have a wider range of applicability. It has been used not only in science and social science, as the others, but in language. Thus, the existing applications suggest its use in a broader context in education.

The next chapter, Conceptual Framework, describes the research objectives based on significant information from the Review of the Literature.

CHAPTER THREE

CONCEPTUAL FRAMEWORK

The Review of the Literature has shown that problem solving models currently being used combine both creative and critical thinking (Bransford & Stein, 1992; Isaksen & Treffinger, 1985). In addition, these models identify three components of problem solving; collecting information, analysing information and forming conclusions (Eggen et al., 1979; McPherson, 1977; Quellmalz, 1987). Current cognitive science theorists are using the terms, declarative knowledge, procedural knowledge and conditional knowledge to distinguish the types of knowledge needed to solve problems (Anderson, 1983; Laird et al., 1987; Rumelhart et al., 1986; Holland et al., 1986). Also, Chi (1987), Marzano et al. (1988) and Paris and Winograd (1990) use the same terms, declarative, procedural and conditional knowledge to explain one's awareness of the three types of knowledge during metacognitive processing. The Review of the Literature established the relationship between declarative knowledge and how it relates to collecting information, procedural knowledge with analysing information and conditional knowledge with forming conclusions.

Voss et al. (1991), in their work on educational reform, emphasize the role of educators to teach problem solving. In addition, studies by Costa (1991), Eggen et al. (1979), Eylon and Reif (1984), Reif (1987) and Swartz and Perkins (1989) show the importance of teaching problem solving skills explicitly. And, based on the work of McPherson (1977) and Quellmalz (1987), to identify key components in problem solving models, a problem solving curriculum would explicitly teach skills in collecting information, analysing information and forming conclusions. Also, according to Isaksen

and Treffinger (1985), and Perkins and Swartz (1992), critical and creative thinking skills should be infused in all components of the curriculum. Thus, both types of thinking should be included in the skills teaching of collecting information, analysing information or forming conclusions. Moreover, Marzano et al. (1988) and Paris and Winograd (1990) state that acquired knowledge can be determined by the students' metacognitive awareness of declarative, procedural and conditional knowledge.

The Holland et al. (1986) framework of Induction has been chosen as the theoretical base for the present study as it has been shown to correspond to the type of problem solving framework needed for classroom instruction in the following ways.

1. The Holland et al. (1986) framework outlines an integrated problem solving approach which includes data collection skills, analysis skills and skills to form conclusions. Models of instruction as outlined by Eggen et al. (1979) suggest a similar integrated approach.
2. The Holland et al. (1986) framework of Induction stresses the importance of learning from experience. In accord with Farnham-Diggory (1972), Piaget (1972) and Vygotsky (1978), the learner is viewed as an active investigator of the environment. Problems are solved based on an interaction between existing knowledge and the environmental situation in question.
3. The Holland et al. (1986) framework of Induction emphasizes the importance of flexible thinking. Through the recategorization of rules or the use of analogy alternative approaches may be developed. Educators have shown that continued, flexible recategorization of information is important in order to permit alternative ways of looking at the given situation (Osborn, 1953; Stanish 1979, 1988).

4. The Holland et al. (1986) framework considers the variability of the environment and provides an explanation of how skills are transferred to solve ill-defined problems. The need to prepare students to solve these ill-defined problems in the workplace has been identified by many such as Bransford et al. (1992), Chi (1987), Reif (1987), Perkins (1988), Smith (1985) and Steier (1989).

5. The Holland et al. (1986) framework has been shown to have a wider range of applicability. It has been used in science, language, social science, etc. Thus, the existing applications suggest its use in a broader context in education.

The terms used in the Holland et al. (1986) framework of Induction; declarative knowledge, procedural knowledge and conditional knowledge have been used as the main source of reference for the data collection and analysis in the study. Worthy to note also, studies in metacognition use the same terms to identify the ongoing types of thinking articulated by the individual while communicating with another (Marzano et al., 1988; Paris & Winograd, 1990).

A preliminary investigation by the Thinking Skills Consortium of Ontario (1989), showed that skills outlined in Ministry of Education curriculum documents, Kindergarten to Senior level (OAC), could be classified according to collecting information, analysing information and forming conclusions (see Appendix A for a copy of the report of the preliminary investigation). Relating the work of the Thinking Skills Consortium (1989) to the Holland et al. (1986) framework of Induction, the students find new and creative ways to collect information, then decide upon the most appropriate information. They find new and creative ways to analyse the collected information then decide upon which type of

analysis is suitable. Finally, through the analysis, they discover new and creative ways to arrive at a conclusion, then decide upon which conclusion is the most appropriate. Thus, creative thinking, along with critical thinking, becomes a significant component of each stage, allowing for more flexibility in thought processing.

Based on the Holland et al. (1986) framework of Induction, the study unit developed for the present research, Atmosphere and Beyond, includes both creative and critical thinking skills. Both types of skills are included in each of the identified steps, collecting information, analysing information and forming conclusions in the problem solving teaching environment. In accord with Costa (1991), Eggen et al. (1979), Eylon and Reif (1984), and Swartz and Perkins (1989), the above study unit was developed within a problem solving environment which teaches problem solving skills explicitly and systematically. In contrast, within a content environment the assumption being made is that students will learn problem solving skills implicitly.

To identify the efficiency of a curriculum with a problem solving orientation, the following objective is proposed:

- to identify student problem solving skills generated in two teaching environments: one based on the Holland et al. (1986) framework of Induction in which skills, collecting information, analysing information and forming conclusions are integrated and coordinated in an explicit problem solving approach; the other, in which skills, collecting information, analysing information and forming conclusions are developed in isolation with a focus on content.

What needs to be investigated are the shifts in knowledge patterns experienced by students who are taught in the problem solving environment. Will these patterns include

more complex declarative, procedural and conditional knowledge? Will these knowledge patterns change with the grade level?

Thus the following four research questions are raised.

Question One: Do the characteristics of the three types of knowledge, declarative, procedural and conditional knowledge, differ between the content environment and the problem solving environment? Critics say that educators must change their role from information based teaching to problem solving skills teaching (Brandt, 1993; Voss et al. 1991). Therefore, the response to this question is important in order to determine whether or not the skills needed to solve problems will be enhanced with the increased emphasis on the systematic teaching of problem solving skills rather than an emphasis on acquiring information.

Question Two: Do students in the problem solving environment show more consistency in their responses to the declarative, procedural and conditional knowledge questions? It is important to note whether or not students will be able to show expertise in problem solving skills on more than one occasion.

Question Three: Is there a relationship between declarative and procedural knowledge? From the Review of the Literature declarative knowledge has been characterized as knowing what and procedural knowledge as knowing how. It should be noted that the relationship between declarative and procedural knowledge will be assessed from information extracted from interviews and not by observation of task performance. The relationship could be qualified as "perceived relationship".

Question Four: After a four month period, to what extent do students recall information, the declarative, procedural and conditional knowledge, that they learned in the problem solving teaching environment? An important prerequisite for transfer or application of skills is whether or not the individual remembers the skills learned.

The next chapter, Methodology, outlines the design of the present research in accordance with the conceptual framework.

CHAPTER FOUR

METHODOLOGY

The study was designed to identify student problem solving skills in two teaching environments, a problem solving environment in which skills of collecting information, analysing information and forming conclusions were taught explicitly and systematically, the other, a content oriented environment in which the assumption was made that students would learn these skills implicitly. In order to conduct such an investigation, an environmental studies curriculum, called Atmosphere and Beyond, based on the Holland et al. (1986) framework of Induction, was developed for junior grades. Included in the curriculum, specifically written for the study, was a section with a content orientation and a section with a problem solving orientation. The procedure for the curriculum design follows a description of the population and the sample for the empirical study.

Population and Sample

Only one school was chosen for the study as extensive commitments were necessary from the administration and teachers in that school. First, a commitment from both the principal and vice-principal was needed in order to provide financial support and arrangement of release time needed for teachers to write the curriculum. Second, the teachers had to make many time commitments regarding the teaching of particular lessons in order to enable similar classroom observations by the researcher. In addition the scheduling of lessons by the teacher was important in order for the interviews to be conducted at the appropriate times for the data collection. For practical reasons, the same group of students was used in the control and experimental design of the study. Different

topics minimized the learning effect of the control portion carried over to the experimental portion of the study.

The study has broad applicability for three reasons. First, the lessons designed are representative of instructional requirements across the province of Ontario. The Ministry of Education Policy Statement for Science in the Primary and Junior Divisions, Science is Happening Here (1988), was used as the base for the curriculum design in all the learning contexts. Second, students participating in the study are representative of the general student population at the junior level as their placement in each classroom covers mixed ability groupings, average, below average and above average in intelligence. Third, although the school is located in a rural community, it draws students from a variety of socio-economic levels because the school is within commuting distance to the city.

All students, $n=84$, in the three junior division classrooms, grades 4, 5 and 6, $n=33$, $n=29$ and $n=22$ students respectively, were invited to participate in the study. An invitation to participate in the study was sent to parents with an attached consent form requiring both student and parent signatures. The letter was structured to inform parents of the purpose of the study and how their children would be involved (see Appendix B for a copy of the letter and consent form).

Seventy-five students accepted the invitation. However, some of these students were absent for portions of the study, consequently results were analysed for sixty-four students, $n=22$, $n=23$ and $n=19$ respectively. Those who chose not to participate in the study were not interviewed for data collection purposes but did participate in all classroom activities as the curriculum was part of the junior level program.

Procedure for Curriculum Design

A study unit, called Atmosphere and Beyond, was developed by teachers which comprised of 60, forty-five minute lessons. The unit was designed to extend over the three terms in a school year, fall, winter and spring, but can also be taught in fewer terms if desired. For the study, the unit was taught in the Winter and Spring terms. The lessons are divided into three sections, Properties of the Atmosphere, People's Relationship with the Atmosphere and What Affects Air Quality (see Appendix C for a complete outline of the unit). The lessons used for the main part of the study are from the section Properties of the Atmosphere. These lessons are divided into segments; the first segment, called Properties of Air, was designed according to a content orientation and the second segment, called the Solar System, was designed according to a problem solving orientation.

Table 1 and Table 2 are summaries of the detailed lesson plans for the teaching of the first and second segments, Properties of Air and The Solar System. Although Properties of Air was taught according to a content orientation, the table shows the teaching steps not only in the content orientation but also what could have been taught in a problem solving orientation. The steps for teaching The Solar System are also recorded for both types of teaching environments. However for this lesson segment, the problem solving teaching orientation was followed. The steps for both teaching environments are given in order that the reader can understand the differences in the two teaching approaches. The steps outlined in all cases are those proposed in the Mousseau Superintendency Planning Model (1989), a proposed approach for lesson planning in the school where the research was conducted. The model is based on the work of Madeline Hunter (Gentile, 1988) who identified essential elements of instruction and supervision. However, the model was adapted by educational staff of the Mousseau Superintendency to meet the needs of that

Table 1

Teaching Outline - Segment One - Properties of Air

STEPS MOUSSEAU MODEL	PROBLEM SOLVING ORIENTED ENVIRONMENT The student shall:	CONTENT ORIENTED ENVIRONMENT The student shall:
SET	- record weather for one week(<i>collecting information</i>)	- record weather for one week(<i>collecting information</i>)
OBJECTIVES	- know the layers of the atmosphere (<i>collecting information</i>) - know air has weight, air occupies space, heat expands air, air rises when heated (<i>collecting information</i>) - analyse current weather based on knowledge from experiments (<i>analysing information</i>) - explain and predict current weather (<i>forming conclusions</i>)	- know the layers of the atmosphere (<i>collecting information</i>) - know air has weight, air occupies space, heat expands air, air rises when heated (<i>collecting information</i>)
METHOD	- view films (<i>collecting information</i>) - observe and participate in conducting experiments (<i>collecting information</i>)	- view films (<i>collecting information</i>) - observe and participate in conducting experiments (<i>collecting information</i>)
CHECK FOR UNDERSTANDING	- make chart to interpret current weather in relation to experiments (<i>analysing information</i>)	- find other experiments to explain concepts taught (<i>analysing information</i>)
GUIDED PRACTICE	- write up experiments with a partner if necessary (<i>collecting information</i>)	- write up experiments with a partner if necessary (<i>collecting information</i>)
INDEPENDENT WORK	- based on analysis chart design questions to ask weather reporter (<i>analysing information</i>)	- design questions to ask weather reporter based on information gained from experiments (<i>analysing information</i>)
EVALUATION	- interpret chart created in CHECK FOR UNDERSTANDING (<i>forming conclusions</i>) - marked according to correct interpretations	- complete test (<i>collecting information</i>) (questions as what happened?) - marked according to correct responses

Note: italics refer to problem solving steps.

Table 2

Teaching Outline - Segment Two - The Solar System

STEPS MOUSSEAU MODEL	PROBLEM SOLVING ORIENTED ENVIRONMENT The student shall:	CONTENT ORIENTED ENVIRONMENT The student shall:
SET	- read legends about the origins of the universe (<i>collecting information</i>)	- read legends about the origins of the universe (<i>collecting information</i>)-
OBJECTIVES	- know names, size of planets and their relation to the sun (<i>collecting information</i>) - explain the travel of light (<i>collecting information</i>) - explain the reason for seasons (<i>collecting information</i>) - compare life in two different places on the earth (<i>analysing information</i>)	- know names, size of planets and their relation to the sun (<i>collecting information</i>) - explain the travel of light (<i>collecting information</i>) - explain the reason for seasons (<i>collecting information</i>)
METHOD	- make an illustration of the solar system using task sheet (<i>collecting information</i>) - observe and participate in conducting experiments (<i>collecting information</i>)	- make an illustration of the solar system using task sheet (<i>collecting information</i>) - observe and participate in conducting experiments (<i>collecting information</i>)
CHECK FOR UNDERSTANDING	- as a class, make a comparison chart to compare activities, at the same time, of people at two different places on the earth (<i>analysing information</i>)	- read chapter in text on the Solar System - answer questions (<i>collecting information</i>)
GUIDED PRACTICE	- in groups, decide on a place to live on the earth - compare to life in own area (<i>analysing information</i>)	- as a class, take up questions - students make corrections (<i>collecting information</i>)
INDEPENDENT WORK	- research in depth one of planets (<i>collecting information</i>)	- research in depth one of planets (<i>collecting information</i>)
EVALUATION	- validity of decision based on information presented in comparison chart (<i>forming conclusions</i>)	- neatness and accuracy of notebooks (<i>collecting information</i>)

Note: italics refer to problem solving steps.

particular school superintendency. The purposes of the teaching model are to reinforce good teaching, to stimulate professional growth and to clarify expectations. It is intended to provide a common framework for supervisory and evaluatory practice throughout the superintendency.

Beside each step in the model, whether the content oriented environment or the problem solving environment, the component of the Holland et al. (1986) framework of Induction, collecting information, analysing information or forming conclusions, is identified in italics. Prior to implementing the study, these components or skills from the teaching outlines were verified by three teacher experts not including the researcher. They were given the outlines from Table 1 and 2 but without the skills identified and asked to name each skill in every step as either collecting information, analysing information or forming conclusions. Their responses were ninety-five percent in accord with the researcher except for two skills in the content oriented environment which were subsequently clarified.

In Table 1, while the headings are the same for the two teaching environments, the skills taught are different. The first difference to note is in the OBJECTIVES step. In the problem solving environment the objectives include the analysis of current weather based on information gained from the experiments whereas, in the content oriented environment, the objectives require the student to know only the layers of the atmosphere and properties of air. The additional analysis and interpretation skills are taught in the CHECK FOR UNDERSTANDING step in the problem solving teaching environment. The students learn to make a matrix chart in which they chart daily weather conditions in relation to the properties of air they have learned. From the chart they learn to interpret weather. But, in

the CHECK FOR UNDERSTANDING step in the content oriented environment the students only collect more information about other experiments that show the properties of air. The EVALUATION step is different. In the problem solving environment the students are evaluated on how they interpret the matrix chart whereas in the content oriented environment they are tested on the information they have collected.

In Table 2 the OBJECTIVES, CHECK FOR UNDERSTANDING and GUIDED PRACTICE steps are different in the two teaching environments. In the problem solving teaching environment there is an added objective, the teaching of the analysis skill of comparing. Based on the information collected about the planets, travel of light and the explanation of seasons the students are to compare places to live and then decide where they would like to live. In the content oriented environment the objectives require the student to know only the planets and understand the travel of light and the reason for seasons. The skill of comparing is taught in the CHECK FOR UNDERSTANDING step in the problem solving environment. The CHECK FOR UNDERSTANDING step is different in the content environment requiring the student to read the chapter in a text that describes the solar system. The EVALUATION step is also different in the two teaching environments. In the problem solving environment the students are assessed on the validity of their decision of a place to live whereas in the content environment their notes are corrected based on the information they have collected in their readings on the solar system.

The main difference between the two teaching environments is the explicit teaching of how to analyse the information that has been collected. The incorporation of analysis skills into problem solving environment leads to different evaluative techniques. In the problem solving teaching environment, the evaluation is based on conclusions formed from the analysis; first, on the interpretation of weather, and second, on a decision where to live.

In the content oriented environment the evaluation is based on information collected, a test on what happened in the experiments and the accuracy of notes.

As the same teachers were teaching both a content orientation and a problem solving orientation sequentially, it was imperative to take precautions in order that they follow each approach as outlined. Prior to the teaching of the first segment, Properties of Air, in the content oriented environment, release time was provided by the principal for one afternoon meeting. The purpose of the meeting was to review, with the teachers involved in the study, the structure of the lessons for that segment. It should be noted that at that time the teachers were not familiar with the approach to be taken subsequently in the problem solving orientation. Then, after the first segment and before teaching the second segment another day for planning was provided. At that time the researcher explained the Holland et al. (1986) framework of Induction to the teachers and then the writing of the lesson segment in a problem solving orientation, The Solar System, was finalized.

Toward the end of the teaching of the unit on the Solar System another day for planning was given to the three classroom teachers involved in the research. The purpose of the planning was to select and design the remainder of the curriculum unit, Atmosphere and Beyond, based on the Holland et al. (1986) framework of Induction. Table 3 provides an outline of the sections selected and the lesson segments chosen for each section. In addition, time allotted for instruction and problem solving skills taught are given.

Referring to Table 3, the second section, called People's Relationship with the Atmosphere consisted of lesson segments on the History of Air Travel, Communication and Recreation. The History of Air Travel, consisting of 14 forty-five minute lessons, was

Table 3
Atmosphere and Beyond Teaching Unit

SECTIONS	PROPERTIES OF THE ATMOSPHERE	PEOPLE'S RELATIONSHIP WITH THE ATMOSPHERE	WHAT AFFECTS AIR QUALITY
LESSON SEGMENTS (number of forty-five minute lessons)	1. Properties of Air (10) 2. The Solar System (10)	1. History of Air Travel (14) 2. Communication (10) 3. Recreation (8)	1. Ozone Layer, Global Warming, Greenhouse Gases (8)
PROBLEM SOLVING SKILL	1. (no explicit skill taught since content oriented environment) 2. Comparing	1. Researching and Observing Relationships 2. Using Time Lines 3. Ordering or Sequencing	1. Finding Central Issue or Main Idea

designed to teach research skills (Halliday, 1986). The students had a choice of researching either non-mechanical machines such as gliders, air balloons, dirigibles, blimps or propelled airplanes or jets or rockets. Then they were taught how to observe relationships (Black & Black, 1990). In small groups, using a class relationships diagram, their problem was to decide upon the most beneficial air vehicle in the world today. The next segment was called Communication, with an allocation of 10 forty-five minute lessons, in which students were to learn the skill of using interval graphs or time lines (Black & Black, 1990) to organize information related to inventions or discoveries such as the telegraph, telephone and satellites. Once the information was collected and organized they were to debate whether or not the world was a better place to live because of these happenings. However, time did not permit the inclusion of this segment of the unit. The last segment was called Recreation, consisting of 8 forty-five minute lessons, in which the students learned the skill of ordering by making a model of an air vehicle. The students in grade six made air balloons to learn the skill (see Appendix C for the pattern in the detailed lesson plans). Time was not allotted for this activity in the grades 4 and 5.

The last section in the unit, What Affects Air Quality, requiring 8 forty-five minute lessons, was designed to teach students the skill of finding the central idea or issue. Using current government publications on the ozone layer, global warming and greenhouse gases they collected information about each issue. Then, using the concept of a Central Idea Graph (Black & Black, 1990), they identified the main problem related to the issues. As a class, the students designed a letter and sent it to major industries to ask how their staffs were attempting to correct current problems related to air pollution. It is important to note that while the main portion of the data collection centered around the first section, Properties of the Atmosphere, the last two sections People's Relationship with the Atmosphere and What Affects Air Quality are also used for data collection. Information

from these sections serves as a follow up or support for information collected in Properties of the Atmosphere.

Instruments

The instruments used for data collection were audio-taped interviews, classroom observations and learning logs.

When referencing the steps in the design of the lessons, the terms collecting information, analysing information and forming conclusions were used. Recall, these terms were identified in the Review of the Literature chapter as the key components in the referenced problem solving models. The relationship between these terms and the terms: declarative, procedural and conditional knowledge from the Holland et al. (1986) framework of Induction was described. As the Holland et al.(1986) framework was chosen as the theoretical base for the study, declarative, procedural and conditional knowledge provide the structure for the design of the questions in the interviews. The reason for the choice is also based on the work of Paris and Winograd (1990) who concluded that students are displaying metacognitive skills if they can verbalize their declarative, procedural and conditional knowledge in relation to a problem. They believe that valuable insights into a person's thinking can be documented and thus interpreted or understood. The design of the interviews is based upon eliciting the declarative, procedural and conditional knowledge from the students about what they have learned. However, it is important to justify the relationship of the components of the problem solving models, collecting information, analysing information and forming conclusions with declarative, procedural and conditional knowledge.

Table 4 presents a matrix which was developed to synthesize the two classifications of thought processing. The column headings, declarative, procedural and conditional knowledge use the types of knowledge identified by Paris and Winograd (1990) in their explanation of metacognition. The row headings, collecting information, analysing information and forming conclusions, are based on the Holland et al. (1986) framework of Induction. The questions in each cell were designed to identify the broad categories of information to be displayed by the students during the interviews.

The categorization of the questions in the cells was validated by eight judges. Each judge was given a numbered, random list of twenty-seven questions and the Table 3 framework without the questions. The judges were asked to place the number corresponding to the question in the cell that they felt described the question. The purpose was to find the question selected most frequently to describe each of the nine cells. Results showed 75% agreement in three of the nine cells, 62.5% in five cells and 50% in the remaining cell. This led to revision of some of the questions. The nine questions were further reduced to three generic questions that exemplify the correspondence between the types of knowledge and the components of Induction. The three generic questions were: "Does the student demonstrate knowledge of facts?" (declarative knowledge/collecting information), "Is any reference given to how to break down information?" (procedural knowledge/analysing information) and "Can the student give reasons why one process is better at a certain time than another?" (conditional knowledge/forming conclusions).

Time Frame for Data Collection

Four interviews were conducted with each student, one prior to teaching the first segment, one between the first and second segment, one at the end of the second segment

Table 4
Matrix for Interview Design

COMPONENT FRAMEWORK OF INDUCTION	TYPE OF KNOWLEDGE		
	Declarative Knowledge	Procedural Knowledge	Conditional Knowledge
Collecting Information	Does student demonstrate knowledge of facts?	Does student talk about how to collect information?	Are facts presented in a variety of contexts?
Analysing Information	Are facts presented in a systematic way?	Is any reference given to how to break down information?	Does student associate/connect processes to different situations?
Forming Conclusions	Are any comments made about the significance of facts?	Are statements present which show how to form conclusions?	Can student give reasons why one process is better at a certain time than another?

Declarative Knowledge refers to facts. It is knowing "what".

Procedural Knowledge refers to the sequence of actions needed to perform a task. It is knowing "how".

Conditional Knowledge refers to when a given strategy is better to use than another. It is knowing "when".

Collecting Information is any skill which involves the procurement/acquisition of data such as reading, listening, viewing.

Analysing Information is the investigation/breaking down into parts of data.

Forming Conclusions is making a judgment, making a decision, forming an inference or solving a problem.

and one at the end of the school year. Four classroom observations occurred, for the same lesson number, in each of the three classrooms. As Environmental Studies was taught at the end of the day, there was not time for students to write in a learning log notebook before leaving for home. At the beginning of the following day they wrote down what they had learned the day before (see Appendix D for a detailed time schedule indicating when the various instruments were used).

Interviews

Each interview was designed according to the three types of knowledge identified by Paris and Winograd (1990). Table 5 provides a generic format of the type of question that was designed for each interview. Note that prior to the research, the form was tested with four students that represented the grade levels in the study. The purpose of the trial interview was to determine whether the students understood the questions, the time needed to conduct the interview and whether the format could be used to talk about a variety of school learning experiences.

The interview questions were adjusted to correspond to the lessons taught. Table 6 outlines the specific questions for each interview in relation to Declarative, Procedural and Conditional Knowledge. Note that the same Declarative Knowledge question was asked in Interview 1 and Interview 2, "Tell what you know about air". However, the Declarative Knowledge question in Interview 1 was to identify student knowledge about air prior to being taught. In Interview 2 it was to identify student knowledge about air after the experiments had been taught. The second Declarative Knowledge question in Interview 2 and the first Declarative Knowledge question in Interview 3 are also the same, "Tell what you know about the solar system". The questions are meant to assess student knowledge

Table 5
Generic Student Interview Form

Question 1.

Declarative Knowledge (knowledge of facts)

Tell me what you know about _____. You told a lot about _____. Tell me something else.

Question 2.

Procedural Knowledge (knowledge of process)

Suppose you have a friend who was absent from school when you learned about _____. How would you go about teaching/telling your friend about the work learned?

Question 3

Conditional Knowledge (knowledge of when to use a certain process)

You have told me how you would go about teaching/ telling your friend about _____. You have used an approach of _____. Now give me some examples of when you could use that same approach again.

Table 6
Declarative, Procedural and Conditional Knowledge
Questions for the Four Interviews

	Interview 1	Interview 2	Interview 3	Interview 4
Declarative Knowledge	Tell what you know about air.	Tell what you know about air.	Tell what you know about the solar system.	Tell what you know about comparing.
Procedural Knowledge	Name a favourite unit of study. How would you teach a friend who had missed school about that favourite unit of study?	How would you teach a friend the experiments they had missed?	How would you teach a friend what they had missed about the solar system?	How would you teach a friend about comparing?
Conditional Knowledge	When could you use that approach again?	When could you use that approach again?	When could you use that approach again?	When could you use comparing again?
Declarative Knowledge		Tell what you know about the solar system.	Tell what you know about comparing.	Pick another skill you have learned. Tell what you know about it.
Procedural Knowledge			How would you teach a friend about comparing?	How would you teach a friend about that skill?
Conditional Knowledge			When could you use comparing again?	When could you use that skill again?

about the Solar System prior and following the teaching of the lessons. Interview 3 had two parts, the first three questions, Declarative Knowledge, Procedural Knowledge, and Conditional Knowledge questions were related to the content about the Solar System.

The second set of questions was designed to assess the three types of knowledge about the skill of comparing that had been taught in conjunction with the solar system. Interview 4, which was conducted at the end of the school year, also had two parts. The first set of questions, Declarative, Procedural and Conditional Knowledge questions were to evaluate student recall of the skill of comparing after a four month period. The second set of questions focussed on student knowledge about an additional skill they had learned in a problem solving environment. Recall that other problem solving skills had been taught between Interviews 3 and 4; during this period, two segments were introduced, People's Relationship with the Air and What Affects Air Quality. The skills taught were researching, seeing relationships, ordering or finding the central idea and the students had a choice about what skill they wanted to talk about in the interview.

During each interview session, prompts were given by the interviewer whenever the student did not understand the task, was providing an irrelevant answer or the researcher required further clarification. These prompts did not give answers but allowed students to expand on their answer. Examples are: "anything else, think about what you have been doing in class, another time other than experiments, tell me about the graph and what do you mean by things?"

Classroom Observations

The researcher observed the same two lessons in the three classrooms for each of the two lesson segments, the content oriented environment and the problem solving environment. The purpose of the observations was to determine the correspondence between the actual teaching and the lesson design. Times to observe depended on teacher and researcher availability. Lessons observed in the content teaching environment, in the lesson segment Properties of Air, were the viewing and discussion of the film, Sky, followed by the experiment lesson on Air Occupies Space. Lessons observed in the problem solving teaching environment, in the lesson segment the Solar System, were the comparison of legends and the identification and placement of planets.

Learning Logs

The purpose of the learning logs was to identify student learning as it relates to the three types of knowledge in the content teaching environment and the problem solving teaching environment. The generic format, presented in Table 7, was posted in each classroom and students were encouraged to follow it. Note that the format proposed to the students corresponds to the structure of the interviews, the identification of declarative, procedural and conditional knowledge. The students were instructed at the end of each daily lesson to write down what they had learned using the guidelines for sentence structure on the posted chart. They were expected to report the information they had learned, the approach or skill they had learned and when they could use their acquired knowledge again.

Table 7
Daily Learning Log Guidelines for Environmental Studies Lesson

1. I know that
2. I know how to First you Then you
.....
3. Another time I can do this is when

Data Collection Procedure

Each audio-taped interview was transcribed verbatim. Using this written documentation, in order to develop a plan for analysis, all comments were extracted from each section of all four interviews. The comments were grouped according to similarity. For instance, the category Giving Materials regrouped statements like give a notebook, give sheets etc. A code was then assigned to each category, such as PGM, meaning Procedural Giving Materials. Validation of the codes by experts was then necessary.

Two judges with extensive experience in curriculum development related to problem solving skills were selected. First the researcher described the structure of the interviews, gave examples of student responses and introduced the coding grid. As a further preparation, the judges were asked to code three transcribed interviews. To determine the extent of judge agreement, they were then requested to code twelve more transcribed interviews. The interviews comprised: one interview for each of the three grades from each of the four interview sessions. The judges, along with the researcher, independently coded all twelve interviews. There was ninety per cent agreement in the assignment of codes between each judge and the researcher's codings. Where a discrepancy occurred, the researcher discussed the discrepancy with the two judges and the category was either clarified or a new category established. The codes were then applied to all the transcribed interviews by the researcher.

The coding was then transferred to a large matrix, one for each grade. The columns of the matrix were reserved for the interviews with the headings Interview 1, Interview 2,

Interview 3 and Interview 4. The rows of the matrix referred to the students, identified only by a number. The codes given for each response to the interviews were then transferred on the matrix for each student (see Appendix E for examples of the codes applied for two students).

The observed behavior patterns were grouped into primary and secondary categories. The secondary categories provide more detailed examples than the primary categories. Table 8 displays the primary and secondary categories for declarative knowledge; each category is defined, assigned a code and provided with an example extracted from the interviews. Each example is referred to by the triplet (interview number, grade, student number). Hence the triplet (4:5-3), refers to Interview 4, Grade 5, Student 3. Note that the first letter of the assigned code indicates the type of knowledge: D for declarative, P for procedural and C for conditional. The primary categories are identified with an asterisk. For instance, when information (declarative knowledge) was presented in ordered fashion, the code *DFO was used; when the facts were presented randomly, *DFR was used. *DCP and *DIM are primary categories which indicated whether students knew the process in question and used either the components of the Holland et al. (1986) framework for their explanation (*DCP) or gave an explanation of the meaning of the process (*DIM), without using the components of the Holland et al. (1986) framework. The codes *Other DKN and *Other DOF were used when student responses did not meet the criteria for the primary categories. In the coding grid for declarative knowledge, there are 6 primary categories and 9 secondary categories.

Table 8
Coding Grid for Declarative Knowledge

DECLARATIVE KNOWLEDGE		
Code	Description	Example
*DFR	facts presented randomly	can't see air and well air floats around places all over you breathe from air (interview 1: grade 4-student 32)
*DFO	orderly flow of facts	well its a type of gas we breathe it in it goes down to our stomach we use it up (1:5-18)
*DCP	clear definition of process	you pick two different things ...pick headings... find information...decide (4:5-27 part 1)
*DIM	identifies meaning	when you have two things and find out their similarities and differences (4:5-28 part 1)
DWC	tell what can be compared	what we did compared the legends the plants (4:4-3 part 1)
DPP	cites purpose for process	see what is going on and maybe get involved (4:4-22 part 2)
DTE	reference to two entities	two things completely different (3:4-33 part 2)
DSD	notation of same and different	what things are the same and what things are different (3:4-33 part 2)
DRI	research/collect information	first is to go to a library (4:4-8 part 2)
DOS	reference to organizational structure	put it in point form and say you've got a graph (3:6-9 part 2)
DFP	mention of final product	well what you come out with in the end (4:4-6 part 2)
DCD	compare to decide	see which one you want to live in (4:4-6 part 1)
MCP	more comments with prompting	anything more (1:4-4)
*Other DKN	doesn't know	I don't know (2:5-9)
*Other DOF	one fact given	you can breathe air you can uh ...(1:5-1)

* refers to a primary code

Table 9 displays the categories for procedural knowledge; its organization is the same as with declarative knowledge. Identified with an asterisk, the primary categories, *PSS and *PTW, indicate whether students used the components of the Holland et al. (1986) framework of Induction to give a step by step explanation of the process (*PSS) or gave a broader explanation (*PTW). The secondary categories refer to student responses which provide more detailed explanation than the primary categories. The *Other DKN code was used when student responses did not meet the criteria for the primary categories. The most common response was that the student did not know the answer. For procedural knowledge, there are 3 primary categories and 22 secondary categories.

The categories for conditional knowledge are displayed in Table 10 which is organized as Table 8 and 9 for declarative and procedural knowledge. The primary categories, identified with an asterisk, *CRL and *COS, showed whether students applied the skill to real life situations (*CRL) or related it to other school subjects (*COS). The *Other DKN code is used when student responses did not meet the criteria for the primary categories; the most common response indicated the student did not know the answer. The secondary categories allow more detailed observation to be recorded. For conditional knowledge, there were 3 primary and 3 secondary categories.

Reading of the student learning logs by the researcher showed that student comments were sporadic as the learning logs were not completed on a daily basis. Consequently, there was no consistency in the lessons that had been recorded. In addition, what was recorded showed that the comments were not contributing additional information to what had already been recorded in the interviews. Because of the inconsistency in reporting, a decision was made by the researcher to exclude the learning logs from the data analysis.

Table 9
Coding Grid for Procedural Knowledge

PROCEDURAL KNOWLEDGE		
Code	Description	Example
*PSS	tell step by step	at first we had to read in books... and then we had to jot it down in charts ... (3:4-7 part 2)
*PTW	tell what learned	well I'd tell population like Australia has the most lead and boxite (1:5-29)
PNT	use notebooks to tell	I'd show the friends all the notes we did in school and let him copy (1:6-1)
PTI	give instructions	I'd start off with giving him a piece of paper and make him fold it and draw a picture on it and then(1:4-23)
PWC	show work done at centres	I'd show him how to do a centre (1:4-26)
PLB	look up in books	ask them if they had any books on it look up information in books (1:4-32)
PSB	demonstrate/show/ science, gym or math	I'd probably set up a net get a ball and I'd start playing with him teach him the skills (1:5-7)
PGM	give materials or notebook to copy/give instructions	let him borrow a book and help him write it out (2:4-3)
PAO	ask other person	and ask for say another friend to come and help (2:4-15)
PGE	guide but do not tell	you just explain things but you do not tell them (2:5-19)
PSN	show notebook	get out my book and ... I would show him my pictures (2:4-12)
PSE	show experiment	I would show her the experiment .. if I had the right things to do it (2:4-9)
PDW	draw/use diagram	teach them how to learn like draw a diagram (2:6-14)

(Table 9 continues)

Table 9 (continued)

PMC	make a chart	and then make up charts with categories (3:4-23 part 2)
PAQ	ask questions	then I'd ask them questions about them (3:6-22 part 1)
PLT	do like teacher	like teach them the way Mr. .. did (3:6-7 part 1)
PTE	reference to two entities	with Australia and Canada (3:4-27 part 2)
PRI	research/collect information	you would do some research on both topics (3:4-8 part 2)
PSD	reference to same and different	and see what is the same...is different (3:4-4 part 2)
PRC	reference to categories	well like sports climate vegetation jobs (3:4-7 part 2)
POS	reference to organizational structure	the school ...teach them stuff about relations like if there are black people and white people and by the teachers (4:5-8 part 2)
PFP	prepare a final product	and then do a note based on your chart (3:4-1 part 2)
PDM	decision to be made	you could choose what place you want to live in (3:4-8 part 2)
MCP	more comments with prompting	let's be specific (1:5-9)
*Other DKN	doesn't know	I don't know (4:4-22 part 2)

* refers to a primary code

Table 10
Coding Grid for Conditional Knowledge

CONDITIONAL KNOWLEDGE		
Code	Description	Example
*CRL	outside and not school related	how to groom a horse (1:5-27)
*COS	other school subjects	science math spelling (1:6-4)
CHS	outside but school related	when I am a teacher (1:5-5)
CDM	decision to be made	to find which ones are worth more money (3:5-24 part 2)
MCP	more comments with prompting	name a couple (1:5-18)
*Other DKN	doesn't know	I don't know (1:5-16)

*refers to a primary code

The next chapter, Results, provides an analysis of the patterns identified in the coding of the interviews.

CHAPTER FIVE

RESULTS

Data were collected from four interviews. The interview questions were designed to identify the declarative, procedural and conditional knowledge acquired by the students exposed to a content oriented environment followed by a problem solving environment. The first interview was conducted prior to teaching the content oriented lessons, the second interview occurred after the content oriented lessons and before the problem solving oriented lessons, the third interview occurred after the problem solving oriented lessons and the last interview followed four months later.

From the transcribed interviews, patterns in responses are categorized according to primary and secondary categories. The primary categories reflect criteria stated within the context of the three types of knowledge, declarative, procedural and conditional. The secondary categories provide a more detailed explanation when necessary.

The main criteria proposed for categories of declarative knowledge are as follows. When facts showed an ordered presentation of information through a connection to a previous fact given, the response was coded as DFO. Note the first initial in all codes refers to the types of knowledge, Declarative, Procedural or Conditional. If the response did not show a connection or association to other facts, it was recorded as random (DFR). When focussing on the definition of a problem solving skill, if a student identified the three components of the Holland et al. (1986) framework of Induction; collecting information, analysing information and forming conclusions, the response was recorded as a precise definition (DCP). If a student demonstrated an understanding of the skill in question but

did not identify all three components of the Holland et al. (1986) framework, the response was recorded as an imprecise definition (DIM).

For procedural knowledge, the categories related to students' explanations of how to perform a skill were used. Responses were recorded as step by step explanations if the student identified the three components of the Holland et al. (1986) framework of Induction (PSS), if not, the response was coded PTW. The letter acronym was selected as students often said that they would just "tell" what they had learned. However, if the student indicated that he/she did not know the answer, the response was recorded as Other. Note the difference between (DCP) and (PSS). Being able to tell about or define a task does not necessarily indicate knowledge in performing the task (Glaser & Pellegrino 1987).

For conditional knowledge, whenever the student indicated use in a real life situation the response was recorded as CRL and if the response indicated application in another subject or school related situation, the response was recorded as COS.

Table 11 provides an introduction to the data base focussing on the primary categories obtained through the application of the coding grid. The table is organized horizontally according to the four interviews and vertically according to the categories established for declarative knowledge (DFO, DFR, DCP, DIM); for procedural knowledge (PSS, PTW) and for conditional knowledge (CRL, COS). In each case if the student response did not fit any of the above categories it was recorded as Other.

Note that the number of responses for each grade are similar for each of the interviews. For declarative knowledge, 12 (3 plus 6 plus 3; 19%) students were presenting

Table 11

Frequency Distribution of Subjects Meeting the Criteria for Declarative, Procedural and Conditional Knowledge

Type of Knowledge	Interview 1	Interview 2/Part 1	Interview 2/Part 2	Interview 3/Part 1	Interview 3/Part 2	Interview 4/Part 1	Interview 4/Part 2
Criteria							
Declarative Knowledge							
DFO ordered	12	34	10	17	23	37	41
DFR random	48	28	33	41	33	23	17
Other	4	2	21	7	9	3	6
DCP precise					11	9	10
DIM imprecise					40	52	50
Other					13	3	4
Procedural Knowledge							
PSS step by step	11	10		2	27	25	37
PTW global	50	54		60	35	38	24
Other	3	0		2	2	1	3
Conditional Knowledge							
CRL real life	9	9		6	59	57	50
COS other subjects	46	46		49	5	5	5
Other	10	9		9	0	2	10

Grade 4, n=22, Grade 5, n=23, Grade 6, n=19.

facts in an ordered manner (DFO) in Interview 1, 41 (14 plus 12 plus 15; 64%) of them did so in Interview 4. A change to note for procedural knowledge is the increase from 11 (17%) students at Interview 1 who provided step by step explanations of how to perform a task (PSS) to 37 (58%) at Interview 4. In Interview 3, Part 2, 11 (17%) students provided a definition of the skill of comparing (DCP) referring to all three components of the Holland et al. (1986) framework of Induction; collecting information, analysing information and forming conclusions. Yet in the same interview, when asked to tell how to compare, 27 (42%) students provided a step by step explanation (PSS) referring to all three components of the Holland et al. (1986) framework. In Interview 4, Part 2, for conditional knowledge, 50 (78%) students were applying the skill learned to a real life situation (CRL) while only 9 (14%) students did so in Interview 1. These results will be augmented and discussed further in more detail. In particular they will form the basis from which the questions raised in the Conceptual Framework may be answered. The research questions are repeated here to refocus attention.

Question One: Do the characteristics of the three types of knowledge, declarative, procedural and conditional knowledge, differ between the content environment and the problem solving environment? Critics say that educators must change their role from information based teaching to problem solving skills teaching (Brandt, 1993; Voss et al. 1991). Therefore, the response to this question is important in order to determine whether or not the skills needed to solve problems will be enhanced with the increased emphasis on the systematic teaching of problem solving skills rather than an emphasis on acquiring information.

Question Two: Do students in the problem solving environment show more consistency in their responses to the declarative, procedural and conditional knowledge

questions? It is important to note whether or not students will be able to show expertise in problem solving skills on more than one occasion.

Question Three: Is there a relationship between declarative and procedural knowledge? From the Review of the Literature declarative knowledge has been characterized as knowing what and procedural knowledge as knowing how. It should be noted that the relationship between declarative and procedural knowledge will be assessed from information extracted from interviews and not by observation of task performance. The relationship could be qualified as "perceived relationship". The Phi-coefficient will be applied to determine whether there is a significant relationship.

Question Four: After a four month period, to what extent do students recall information, the declarative, procedural and conditional knowledge, that they learned in the problem solving teaching environment? An important prerequisite for transfer or application of skills is whether or not the individual remembers the skills learned. The Phi-coefficient will be applied to assess the significance of the relationship between the three types of knowledge and the two interviews.

In addition to the above four questions, a Chi-square analysis will be applied to the second part of Interview 3 and the first part of Interview 4 to determine the level of association between grade level and knowledge acquisition.

In reporting results, examples of student responses to the interview questions were extracted from the transcribed interviews. These examples will be identified by a code consisting of three parts, interview number, grade and student identification; for example, (4:5-3), refers to Interview 4, Grade 5, Student 3.

Response to Question One: Knowledge Characteristics

From the Review of the Literature, Holland, Holyoak, Nisbett and Thagard (1986) refer to ordered associations within the human cognitive system to facilitate retrieval of information. Derry (1990) and Hunter (1992) claim that recall of information is greatly aided when a student's idea network is organized. Eylon and Reif (1984) refer to hierarchial structures of knowledge. In order to determine the organizational structures students have acquired, the declarative knowledge question in the interviews, "Tell what you know about ", provides such information. In Interview 1, the students were asked what they knew about air. For Interview 2, Part 1, they were asked what they knew from the experiments and in Interview 2, Part 2, what they knew about the solar system. In Interview 3, Part 1, which followed the instruction in the first problem solving teaching environment, the students were asked again about the solar system and then, in Part 2, what they knew about the skill of comparing. In Interview 4, four months later, they were asked again what they knew about comparing in Part 1 and, in Part 2, about another skill of their choice which they had studied. Responses were recorded as either ordered or random. In order for a student to be given credit for an ordered response, the facts given must have shown a connection or association to the previous facts given.

To convey the flavour of responses made by students, Table 12 provides a sample of statements extracted from interviews for each type of knowledge either declarative, procedural or conditional. In Table 12, for each excerpt, the targeted type of knowledge together with the criterion to be met are identified: ordered or random for declarative knowledge, step by step explanation or global explanation for procedural knowledge and use in other school subjects or use in real life situations for conditional knowledge.

Table 12

Student Responses for Declarative, Procedural
and Conditional Knowledge in Relation to Identified Criteria

Declarative Knowledge - Ordered Response (1:6-13)*

"well it is invisible, it moves around in the space above the ground with wind which carries it, you breathe it in, it contains oxygen and carbon dioxide, you inhale the oxygen and you exhale the carbon dioxide, plants do breathe the opposite way"

Declarative Knowledge - Random Response (1:6-4)

"pollution, if circulated in air, we breathe air, we do research about air and learn things about it, spaceships, kites and planes fly through air, we .. air is uhm a special part of life and that's about it"

Procedural Knowledge - Global Explanation (3:5-28 Part 1)

"well I'd explain to them about some of the planets and some of the experiments and how it happened and some of the things to maybe look at some of the information about the planets and some of the information about our planet coming in toward the sun and the seasons"

Procedural Knowledge - Step by Step Explanation (3:5-28 Part 2)

"step by step?"..."well I'd tell them to pick something that they'd want to compare and maybe leave out place two for a little while and go to place one and concentrate on it and get all the information that you can under the categories that you'd like it under and drop place one and go to place two and kind of do a research on that and then maybe write it, some of the things down in point form on a chart and look at them maybe and decide whether they were different or the same"

Conditional Knowledge - Use in Real Life Situations (2:4-7 Part 1)

"well maybe if I went to some special thing like guides and they missed one night and I'd show them what they had missed in guides"

Conditional Knowledge - Use in Other School Subjects (2:4-4 Part 1)

"in math, in art, that's it"

*(1:6-13) refers to interview 1: grade 6 - student 13

Finally, the source of the quote is provided with the triplet (interview number, grade, student number).

Referring to Table 12, while both responses for declarative knowledge refer to air, the ordered presentation shows more focussed and structured thought processing as the student concentrates on one aspect of air, its composition.

For procedural knowledge, Glaser and Pellegrino (1987) in their studies of intellectual processes, suggest that the improvement of the skills of learning will take place through the exercise and development of procedural or problem solving knowledge in the context of specific domains. The second question in each interview segment was aimed at identifying procedural knowledge. Each student was required to tell how he/she would teach or explain the work he/she had learned to a student who had been absent. Thus the term "teach" was frequently used in the interviews and the meaning was clear to the students. Specifically, in Interview 1, after choosing a favourite lesson to talk about, the student was asked to tell how he/she would teach what he/she had learned in that favourite lesson. In Interview 2, he/she was required to tell how he/she would explain the work on the experiments. In Interview 3, Part 1, each student was asked how he/she would teach what had been missed about the solar system and then, in Part 2, how he/she would teach the skill of comparing. Four months later, in Interview 4, Part 1, each student was asked again how he/she would teach comparing and in Part 2, how he/she would teach a friend a skill they had selected to talk about. Responses were recorded according to step by step explanation or global comment. Step by step explanation required the student to follow a systematic account of how he/she would teach or explain the work. Global comments referred to just "tell" the student what he/she had missed or loan him/her a notebook to copy the work. Referring again to Table 12, for procedural knowledge, in the step by step

explanation the student even asked if the response should be step by step. Yet, in the same interview, when the same student was asked how to teach the content, the student was not specific about the number or planets or experiments to be explained. The term "some" was continually used, such as some of the planets, some of the things and some of the information. A possible reason for the difference in the two procedural knowledge responses is that the teaching of the skill of comparing followed an explicit step by step approach which resulted in the student knowing that a step by step explanation was an expected response.

Conditional knowledge has been cited as a critical component in teaching and training programs (Reif 1987). As an indicator that students are aware of how to apply their knowledge to other problem solving tasks, the teaching of conditional knowledge is a continuous challenge, and consequently, a prime goal for educators. The third question referred to such knowledge. The students were asked to tell when they again would use a skill they had learned. Responses were recorded according to: use in other school subjects and use in real life situations. In Table 12, for conditional knowledge, in the first example the approach that the student cited was copying and giving materials. While the student said that these approaches could be used in math and in art, the student could have given a response related to a real life situation such as copying rules to a game for a friend and giving material to make a craft.

Table 13 records the frequency of subjects meeting selected criteria for each grade, as well as for the total sample, for declarative, procedural and conditional knowledge in each of the interviews. The table is organized according to the sequences of the interview questions. Preceding each question, the targeted type of knowledge is identified:

Table 13

Frequency of Responses Per Grade Meeting the Selected Criteria for
Declarative, Procedural and Conditional Knowledge*

Interview Declarative, Procedural, Conditional Knowledge Question (D,P,C)	Grade 4 (n=22)	Grade 5 (n=23)	Grade 6 (n=19)	Total (n=64)
Interview 1 - Content				
D - Tell what you know about air.	3	6	3	12
P - How would you teach favourite lesson?	3	1	7	11
C - When could you use approach again?	2	6	1	9
Interview 2 - Content				
D - Tell what you know about air.	11	8	15	34
P - How would you teach experiments?	3	5	2	10
C - When could you use approach again?	3	4	2	9
D - Tell what you know about solar system.	3	4	3	10
Interview 3 - Problem Solving				
D - Tell what you know about solar system.	7	3	7	17
P - How would you teach solar system?	1	0	1	2
C - When could you use approach again?	3	3	0	6
D - Tell what you know about comparing.	7	10	6	23
P - How would you teach comparing?	6	13	8	27
C - When could you use comparing again?	21	22	16	57
Interview 4 - Problem Solving				
D - Tell what you know about comparing.	10	14	13	37
P - How would you teach comparing?	9	10	6	25
C - When could you use comparing again?	21	18	18	57
D - Tell what you know about selected skill.	14	12	15	41
P - How would you teach selected skill?	13	15	9	37
C - When could you use skill again?	16	20	17	53

*Criteria: **D** - ordered presentation of facts must show a connection or association to previous fact given; a sequence should be evident. **P** - step by step explanation must be given. **C** - answer must be a real life situation not school related.

Declarative (D), Procedural (P) and Conditional (C). To make results more transparent criteria are highlighted at the bottom of the table.

From Table 13, the frequency distributions across the grades are relatively uniform. For declarative knowledge, in the first question in Interview 1 and 2, there was an increase in responses after the lessons on the properties of air from 12 (19%) to 34 (53%). However, for procedural knowledge, when students were asked how they would teach skills they had learned, the frequency of responses was similar for both Interview 1 and Interview 2 (11 responses and 10 responses). In addition, for conditional knowledge there was no increase in responses (9 responses on both occasions) when asked when they again would use the skill they had learned. Thus, in relation to the content teaching environment, there was an increase in declarative knowledge from Interview 1 to Interview 2. However, procedural and conditional knowledge remained relatively constant. Note that in Interview 1 the students were talking about how they would teach a favourite lesson and in Interview 2 the students were talking about teaching the experiments. While different, both interviews followed formal teaching of the topic in question. In Interview 2, Part 2, before the lessons on the solar system, the students were asked the declarative knowledge question, "Tell what you know about the solar system". Then in Interview 3, Part 1, after the lessons on the solar system in the problem solving teaching environment, they were asked the same question. There was an increase in ordered responses from Interview 2 to Interview 3 (10 to 17 responses).

In Interview 3, Part 1, while the content of the solar system was taught in a problem solving environment, the results for procedural and conditional knowledge (2 responses for procedural knowledge and 6 responses for conditional knowledge) are even less than those for procedural and conditional knowledge from Interview 1 and Interview

2. There appears to be no effect on these two types of knowledge, despite the content being taught in a problem solving environment. Thus, content taught in a content environment or a problem solving environment seems to produce the same learning effect for declarative, procedural and conditional knowledge.

Following the teaching of comparing, in Interview 3, Part 2, when the students were asked the declarative knowledge question , "What is comparing?", the responses showed 23 students (36%) could give an ordered response and a notable increase to 37 students (58%) continued to be able to give an ordered response four months later in Interview 4, Part 1. In particular, the change to note in Interview 3, Part 2 and both parts of Interview 4, is the high number of responses for procedural and conditional knowledge. In addition, a comparison of Interview 3, Part 2 and Interview 4, Part 1, indicates that students are able to recall the declarative, procedural and conditional knowledge questions after a four month period.

The results of Interview 4, Part 2 further demonstrate the change in responses for declarative, procedural and conditional knowledge when students are taught problem solving skills in a problem solving context. In Interview 4, students were asked to talk about another skill they had learned in relation to the three types of knowledge. Similar to the responses for the declarative knowledge questions about comparing, 41 students (64%) gave an ordered response. For procedural knowledge, 37 students (58%) were able to give step by step explanations of how to perform the selected skill. And, for conditional knowledge, the responses were similar to the two conditional knowledge questions for comparing.

In summary, the increase in responses meeting the criteria for declarative, procedural and conditional knowledge related to a problem solving skill, suggests strongly that skills are better improved in a problem solving teaching environment.

Other Pertinent Results

The results show that there was little change in the ordered presentation of declarative knowledge of content from the content environment to the problem solving environment. Specifically, in Interview 3, Part 1, despite the content about the solar system being taught in the problem solving environment, the results for declarative knowledge are similar to those from Interview 1 and 2 when the content was taught in a content oriented environment. However, in Interview 3, Part 2, the response increased for the declarative knowledge question about the skill of comparing. Possibly the content of the solar system was more difficult as students are not able to relate to the many unknowns of the universe as to the other more familiar topics such as the experiments on air or the study of animals. However, the content taught for the solar system was extracted from grade level texts. In addition, reference to Table 11 does show that 41 students (64%) recalled information but in a random fashion. Totalling the ordered and random presentation of information, 58 students (91%) did provide information about the solar system. Therefore, students have learned information about the solar system but are not showing evidence of organizational structures within their cognitive systems. The importance of ordered organizational structures has been stressed by Derry (1990), Eylon and Reif (1984) and Hunter (1992).

Referring to Table 13, the total increase in overall responses for declarative knowledge from Interview 3, Part 1 to Interview 3, Part 2 is worthy of reference at Grade

5. Note that 3 students were able to give an ordered response for the content about the solar system while, in the same interview, 10 gave an ordered response for the skill of comparing. These students demonstrated weak factual knowledge about content but were able to give the facts about the skill of comparing. As an example, for factual knowledge about the solar system, the student said: "I don't really know that much, uhm, I always, when we talk about it I always forget the stuff, I don't know much about it". Then for the skill of comparing the same student said: "Well you got to pick two things and you gotta ask questions about them and see if they're different or the same, it's good or bad" (5:3-4). Possibly these students are weak academically and despite their lack of ability to recall the content, the knowledge of a problem solving skill is within their capability. As recommended by Bransford et al. (1992), Greeno (1990), Heller (1983), Holyoak (1990) and Reif (1987), the skill likely had been taught to have flexible use and the students possibly learned the skill through an association to which they could relate. The result demonstrates that while some students may have difficulty relating to content, they benefit from the skills teaching when taught with the focus on problem solving.

Another pertinent observation is the number of students who recalled the skill of comparing four months after the teaching of the skill. In the interim, students were taught other skills within the context of other topics. Yet, students were able to maintain their level of knowledge for comparing. In fact, the increase in responses for declarative knowledge from 23 students (36%) to 37 students (58%) indicates they were increasing their knowledge. Also, in Interview 4, Part 2 there is a continued increase in subjects who meet the criterion for each of declarative, procedural and conditional knowledge. This result may be attributed to student choice. Students chose the skill they wished to talk about from the skills they had learned and consequently would select the skill that they knew well. But in Interview 3, Part 2 and Interview 4, Part 1, they were assigned the skill

of comparing. Also to be considered is that students are becoming more accustomed to a problem solving teaching environment and thus continually developing more efficient problem solving skills.

Using the frequencies from Interview 3, Part 2 and Interview 4, Part 1, a 2 X 3 (2 interviews, 3 grades) contingency table was obtained for each type of knowledge, declarative, procedural and conditional. No significant association was observed between the three grades and the two interviews. For the question, "Tell what you know about comparing", Chi-square = 0.54, $df = 2$, $p > 0.05$; for the question, "How would you teach a friend about comparing", Chi-square = 1.19, $df = 2$, $p > 0.05$ and for the question, "When would you teach comparing again?", Chi-square = .52, $df = 2$, $p > 0.05$.

From the analysis of data in response to Question One, conclusions emerge which have an important impact on teaching and provide avenues for further research. First, it seems that content can be as effectively taught in a problem solving environment as opposed to a content environment. Thus the research question arises. What is the effect of the learning environment on the teaching of content? From the Review of the Literature, advocates of problem solving skills teaching environments suggest the integration of content with problem solving skills (Eggen et al. 1979, Glaser & Pellegrino, 1987). The present study, while limited, does suggest little effect on content knowledge whether students are taught in a content environment or a problem solving environment.

Second, the results from the study show there is a strong indication that the problem solving environment enhances the learning of problem solving skills. Heller and Reif (1982) and Swartz and Perkins (1989), believe that students must be taught explicitly problem solving skills within a problem solving context. Thus from the analysis of the

present study and the beliefs of the forementioned theorists, the following research begins to have particular importance. "Does the teaching environment play a role in the learning of problem solving skills?" Highlighted in The Common Curriculum (1993) is the need to teach problem solving skills but there is no reference to any specific teaching environment. Based on the experience of the researcher, current trends in education promote co-operative learning environments or activity based learning environments but whether the focus is on content or problem solving is a consideration made by the teacher.

Response to Question Two: Content versus Problem Solving

The response to Question One has shown the differences in the characteristics of the three types of knowledge, declarative, procedural and conditional between the content teaching environment and the problem solving teaching environment. Question Two now responds to the question, "Do students in the problem solving environment show more consistency in their responses about problem solving skills?" It is important to know whether or not students are able to show expertise in problem solving skills on more than one occasion. Thus, the frequency distributions of responses for the content related interviews and the problem solving related interviews will be analysed for declarative, procedural and conditional knowledge.

In order to facilitate comparisons, the results are now grouped according to interviews related to content and problem solving for each of declarative, procedural and conditional knowledge. In the content teaching environment, students were taught problem solving skills implicitly while in the problem solving environment, problem solving skills were taught in a systematic step by step manner. One of the main purposes of such systematic instruction was to facilitate meaningful associations within the student's

cognitive system. The importance of such associations or connections has been recognized and is an integral component of the Holland et. al (1986) framework of Induction.

Anderson (1983), Derry (1990), Gagne (1985) and Hunter (1992) identify the importance of well structured and well elaborated cognitive networks. The declarative knowledge question in the interviews, "Tell what you know about", provides information on the cognitive structures students have formed in their approach to presenting facts related to content or to a problem solving skill. In Interview 1, the students were asked what they knew about air. For Interview 2, Part 1, they were asked what they knew about air from the experiments and in Part 2, what they knew about the solar system. In Interview 3, which was the first problem solving teaching environment, for Part 1, the students were asked what they knew about the solar system and then in Part 2, what they knew about the skill of comparing. Finally, in Interview 4, Part 1, after a four month period, they were asked again what they knew about comparing then, for Part 2, what they knew about another skill they had learned.

Bransford et al. (1992), Eylon and Reif (1984), Heller (1983), Heller and Reif (1982) and Reif (1987) stress the importance of the explicit teaching of problem solving skills. For procedural knowledge, the comparison is related to the step by step explanation of how to do a task. Asked as the second question of each interview, the student was required to tell how they would teach a friend the work they had missed. Specifically, in Interview 1, after choosing a favourite lesson to talk about, the students were asked to tell how they would explain what they had learned in that favourite lesson. In Interview 2, they were required to tell how they would explain the work on the experiments. In Interview 3, Part 1, they were asked how they would teach what had been missed about the solar system and then in Part 2, how they would teach the skill of comparing. Then four

months later, in Interview 4, Part 1, they were asked how they would teach comparing again and in Part 2, how they would teach a friend the skill they had selected to talk about. Responses were recorded as global or step by step. A step by step response required a systematic explanation, otherwise it was recorded as global.

Recognizing the importance of transfer of learning to solve real life problems (Bransford et al., 1992; Perkins & Salomon, 1988; Reif, 1987; Schoenfeld, 1991), it is important to show if students are better able to apply their acquired knowledge to real life situations after being taught in the content teaching environment or the problem solving teaching environment. For conditional knowledge then, the comparison was made of the two environments in relation to how students perceived the application of their knowledge. The third question in each section of the interviews asked the students when they would use what they had learned again. Specifically, in Interview 1, after they explained how they would teach a classmate about a favourite lesson, they were asked when they would use the same approach again, for example, the approach of telling, demonstrating or drawing. In Interview 2, they were asked when they would use the approach they had used to teach the experiments. Then, in the first part of Interview 3, they were asked when they would use the approach they had used to teach the solar system again. In the second part they were asked when would they use comparing again. In Interview 4, after the four month period, March to June, they were asked when they would use comparing and lastly, when they would use the skill they had chosen to talk about. Responses were recorded as use in other school subjects or use in real life situations.

Examples of ordered and random responses from the same student (Grade 6, Student 12) for each of the declarative knowledge questions in the four interviews are provided in Table 14. The criterion for an ordered response must show a connection or

Table 14

**Declarative Knowledge Responses for Content and Problem Solving Questions
from One Student in Relation to Identified Criteria**

Content - Random Response (1:6-12)*

"air is made up of three chemicals oxygen carbon dioxide and I'm not sure...is weightless we breathe with it it surrounds the earth"

Content - Ordered Response (2:6-12 part 1)

"air has weight it takes up space it ..heat expands air .. that's it"

Content - Random Response (2:6-12 part 2)

"the solar system has over two billion stars the moon is there is a lot of planets in it its the biggest thing we know of it is always surrounding us"

Content - Random Response (3:6-12 part 1)

"the solar system I think there is I think nine planets mercury oh venus earth mars jupiter saturn uranus neptune pluto.... the sun is ... if you put every planet together except for jupiter.. jupiter is still bigger that's all"

Problem Solving - Random Response (3:6-12 part 2)

"you can compare almost anything all you have to do is just get information about it and write it down"

Problem Solving - Ordered Response (4:6-12 part 1)

"comparing is when you take one thing and you compare it to another by finding out what is the same and what is different about them"

Problem Solving - Ordered Response (4:6-12 part 2)

"well research is you have to look up on something let's say you could go to a library read a book about it ask somebody you could watch it"

*(1:6-12) refers to interview 1: grade 6 - student 12

association to the previous fact given, otherwise it is recorded as random. The table is organized under two headings, content responses and problem solving responses accompanied by the criterion followed by the identification number. Recall the index has three components: number of interview, grade and student identification as (1:5-25), referring to Interview 1, Grade 5, Student 25.

Referring to Table 14, the random responses show no connection to the previous thought. While the student is referring to the topic, whether it be air, the solar system or comparing, he/she gives isolated comments showing no flow of thoughts or building on information already given. The ordered responses for content reflect the purposes of the experiments and for problem solving, the student provides a sequence of facts to describe the skill of comparing.

For procedural knowledge, Table 15 gives examples of step by step explanations and global explanations from another student. To meet the criterion for a step by step explanation, the student must have provided a sequential or systematic outline of how to perform the skill in question. If the criterion was not met, the response was recorded as global. The table is organized under two headings, content responses and problem solving responses accompanied by the identified criterion followed by the identification number; for instance (1:6-9) refers to number of interview, grade and student identification.

For Table 15, the step by step explanations follow an ordered presentation of thoughts. The answers use words such as first and then to indicate a sequence. The global

Table 15

Procedural Knowledge Responses for Content and Problem Solving Questions
from One Student in Relation to Identified Criteria

Content - Step by Step Explanation (1:5-8)*

"I like the art project we did well first I would invite them over and then I would get a magazine or something and then I would get them to pick out a picture they liked and then I would tell them to cut it in half horizontally or vertically uhm and then glue half of it on to a piece of paper then you take the other piece of paper and you draw the rest of it and you're done and compare it to the picture you drew it off of and see if it would look good"

Content - Global Explanation (2:5-8 Part 1)

"well either I would go experiment by experiment or I would just like put write the experiments together like the all the demonstrations together like and I would see OK the things I learned about them at ES I could tell them like but I didn't remember them I could look at my ES and tell them"

Content - Global Explanation (3:5-8 Part 1)

"well I would if they didn't want to like take a whole lesson up by learning about the solar system or a whole week or something like just let them borrow my book and let them read it over and let them know that they didn't know"

Problem Solving - Step by Step Explanation (3:5-8 Part 2)

"first choose a land and I would make them sign out a book on this place and just look up the thing they are going to study about and they're going to put down categories like transportation housing climate and so on and after they are finished that they have to write it on a little square sheet full of squares and you have to write up the stuff about OK there's the categories of climate and so on climate and place 1 Arnprior and Ottawa and place 2 is the one you chose out of Canada and then you put same or different on the last category"

Problem Solving - Global Explanation (4:5-8 Part 1)

".... I would be telling her that to pick a place in Ontario and then write what you know about it and then and then you'd pick another place in the world and find its differences and compare it to the one you picked before that "

Problem Solving - Global Explanation (4:5-8 Part 2)

"either I would take them to a museum or show them around the school because like the school because you can like what's the word I am trying to think of you can teach them stuff about relations like if there is black people and white people by the teachers which we don't really like supply teachers"

*(1:5-8) refers to interview 1: grade 5 - student 8

explanations often make reference to loaning or referring to notebooks in order for students to learn the information. Systematic procedures are not used.

Conditional knowledge responses from one student for the four interviews are displayed in Table 16. A real life situation response is categorized as non-school related. If it did relate to school it was recorded as other school subjects. The table is organized as the tables for declarative and procedural knowledge, under the two headings, content responses and problem solving responses, followed by the identification index as (1:6-7), referring to number of interview, grade and student identification.

Referring to Table 16, real life situation responses refer to sports, houses or computers. Other school subjects responses make direct reference to other subjects.

The number of interviews in which the students met the criteria for declarative, procedural and conditional knowledge are displayed in Table 17. Beside the headings, content and problem solving, the interview is identified. Under each heading, the number of interviews and the three types of knowledge along with the respective criterion are listed. Recorded for each are the frequencies of responses per grade along with the total responses.

Referring to Table 17 for declarative knowledge in the content interviews, a sizeable number of students did not produce ordered responses. Totalling the responses related to content for one interview and no interview, 47 students (73%) gave an ordered response on at most one occasion. However, in the problem solving interviews, there were 28 students

Table 16

Conditional Knowledge Responses for Content and Problem Solving Questions
from One Student in Relation to Identified Criteria

Content - Real Life Situations (1:4-15)* ".... and the number of a house or something .. phone number address" Content - Other School Subjects (2:4-15) "with some of the other subjects" Content - Other School Subjects (3:4-15 part 1) "in other subjects"
Problem Solving - Real Life Situations (3:4-15 part 2) "let's see if you were going to compare sports or hockey teams for instance the senators and what's another hockey team..." Problem Solving - Real Life Situations (4:4-15 part 1) "you could compare computers to see which one is worth buying" Problem Solving - Don't Know (4:4-15 part 2) "uhm...."

*(1:4-15) refers to interview 1: grade 4 - student 15

Table 17

Frequency of Responses Per Grade Meeting the Criteria for Declarative, Procedural and Conditional Knowledge in Content and Problem Solving*

Teaching Focus				
Number of Interviews Type of Knowledge - Criterion	Grade 4 (n=22)	Grade 5 (n=23)	Grade 6 (n=19)	Total (n=64)
Content (1, 2:1, 2:2, 3:1)**				
Four Interviews				
D - ordered response	0	0	0	0
Three Interviews				
D - ordered response	3	3	4	10
P - step by step explanation	0	0	0	0
C - real life situation	0	1	0	1
Two Interviews				
D - ordered response	3	1	3	7
P - step by step explanation	1	0	2	3
C - real life situation	2	1	1	4
One Interview				
D - ordered response	8	10	10	28
P - step by step explanation	4	6	6	16
C - real life situation	6	8	1	15
No Interview				
D - ordered response	8	9	2	19
P - step by step explanation	17	17	11	45
C - real life situation	14	13	17	44
Problem Solving (3:2, 4:1, 4:2)				
Three Interviews				
D - ordered response	3	4	3	10
P - step by step explanation	4	4	2	10
C - real life situation	14	16	13	43
Two Interviews				
D - ordered response	7	9	10	26
P - step by step explanation	2	9	6	17
C - real life situation	8	5	6	19
One Interview				
D - ordered response	8	6	5	19
P - step by step explanation	12	8	5	25
C - real life situation	0	2	0	2
No Interview				
D - ordered response	4	4	1	9
P - step by step explanation	4	2	6	12
C - real life situation	0	0	0	0

*Type of Knowledge: D - Declarative, P - Procedural, C - Conditional

** 2:1 refers to Interview 2, Part 1

(44%) who produced ordered responses on at most one occasion. Thus for the problem solving interviews, over half the students produced ordered responses (36 students, 56%) on at least two occasions.

Also, from Table 17, it is important to note the large number of students who gave ordered responses related to content (28 students, 44%) at one interview. Referring back to Table 13, Interview 2, Part 1, a total of 34 students gave ordered responses. This total is disproportionate to the total responses for the other content interviews where, from Table 13, 12 students, 10 students and 17 students respectively, gave ordered responses. The reason can be attributed to the content knowledge being questioned in Interview 2, Part 1. When the students were asked, "Tell what you know about air", their answers reflected the purpose of the experiments such as; air has weight, air occupies space, air has pressure, heat expands air and air rises when heated. The criterion for an ordered response was difficult to apply as the experiment lessons were independent of each other. Therefore the criterion was modified. Students were given credit for an ordered response if they recalled the purpose of the experiments despite the sequence of the information given. Therefore, from Table 17, any inference from the inflated frequency of 28 students for content at one interview is questionable.

Referring to Table 17, for procedural knowledge, only 3 students (5%) gave step by step explanations in at least two interviews related to content. However in the same number of interviews, 27 students (42%) gave step by step explanations related to problem solving. Worthy to reference also, 45 students (70%) did not refer to step by step explanations in any of the content related interviews but only 12 students (19%) did not give a step by step explanation in any problem solving related interview. Thus a comparison of the frequencies of step by step explanations for content and problem solving

shows that students appear to articulate step by step explanations more readily from a problem solving teaching context.

Referring to Table 17 again for conditional knowledge, 44 students (69%) failed to meet the criterion on any content related interview while everyone (100%) did so for problem solving. More specifically, totalling the responses for three interviews and two interviews for each of the content and problem solving contexts, 5 (i.e. 1 plus 4) students (8%) met the criterion for content while 62 (i.e. 43 plus 19) students (97%) met the same criterion for problem solving. The results show how the explicit teaching of problem solving skills enhances the perceived application of knowledge in real life situations. In addition, these results are in accord with the work of Bransford et al. (1992), who state that problem solving experiences with an emphasis on conditional knowledge are important aspects of learning. Further support for transfer of knowledge based on teaching in a problem solving context follows.

Students who talked about using a skill in a real life situation often said why they would use the particular skill. If they did not, the researcher asked them to tell why they would use the skill in question. Examples follow of the same student's response for each question related to a problem solving skill. For comparing, in Interview 3, the response was, "like you could compare countries if you were going to move somewhere to see which one has a better environment and better temperature and all that... you could compare sports to see which ones you'd get more money in and get entered more"(3:4-6). Then in Interview 4, Part 1, after the four month period, the same student gave the following reason for comparing: "houses to see which one would be suitable for your family like if you had a big family you would want a big house and a small one you'd want a small one". And in Part 2 for the skill finding the main idea, the response was: "fruit, trees ... well for

the fruit and that, find out which ones are not poisonous and you can eat them and flowers, see which ones bloom earlier and smell the nicest for trees, probably ones that are big and give a lot of shade"(4:4-6). In summary, the student is not only transferring skills to real life but giving a reason. Being able to give a reason for using a skill further demonstrates understanding of that skill.

The number of students who gave a reason for using a skill in a real life situation is recorded in Table 18. From Table 18, for Interview 3, Part 2, 46 students (71%) were able to give a reason for comparing shortly after they had been taught the skill. And, in Interview 4, Part 1, after the four month period, responses showed that students preserved the skill quite well. Forty-four students (68%) continued to be able to give a reason for comparing. In Interview 4, Part 2, while 33 students, (51%), were able to give a reason for other skill learned, the lower frequency may be attributed to the fact that the students had received instruction in four other skills in the four month period after comparing had been taught. Therefore, they had not had the same amount of exposure to the particular skill in question. It appears that more integration had occurred with comparing but it also may be entertained that comparing is easier to learn. However, based on the results and the work of Reif (1987), who states that students must be given help to integrate their accumulating knowledge, the explanation that more integration had occurred with comparing is more tenable.

A Chi-square test was conducted to determine if there were any significant patterns related to students giving a reason for comparing. Using results for conditional knowledge from Table 16, Interview 3 and Interview 4 part 1, no significant association was observed between the three grades and the two interviews (Chi-square = 1.19, df = 2, $p > 0.15$).

Table 18

Number of Subjects Per Grade Meeting the Criterion for Conditional Knowledge in Problem Solving Teaching Environments*

Time Question	Grade 4 (n=22)	Grade 5 (n=23)	Grade 6 (n=19)	Total (n=64)
Interview 3 - Part 2				
When would you use comparing again?				
Gave Reason	17	17	12	46
Interview 4 - Part 1				
When would you use comparing again?				
Gave Reason	15	16	13	44
Interview 4 - Part 2				
When would you use selected skill again?				
Gave Reason	11	14	8	33

*Criterion: student gives reason for using skill

Included in the coding of the collected data was the number of times students used notebooks or other resources to help them explain the skill in question. A pattern emerged in the problem solving teaching environment which showed a lower frequency in the number of times the students were relying on notebooks or other resources to explain a skill. Thus what appeared to be occurring was a shift away from the need to use notebooks or other people to aid in the explanation of how to do a task. Examples follow of responses showing the decrease in the use of outside resources from the same student in a content lesson and then in a problem solving lesson. In the content lesson the student said: "I would give him my book so he could draw the diagrams and if he did not quite understand it then I would explain it to him just so he knew what exactly what the experiment meant" (2:6-9). Later, in the problem solving lesson the student said: "Well first I'd get a sheet of paper and I'd ask them to draw me a chart with a couple of columns and two rows or three rows and then I'd ask them to think of two subjects they liked that were sort of, that had a few things in common and I'd tell them to write them down in the two rows then I'd tell them to write same or different at the bottom and then I'd say well the next thing you do is get some, think of some headings that would go with the things in common or that are different between the two things and then I'd say write them down in each column, so after the person did that I'd say now go to the library or somewhere and get some books on these two subjects and research on them, on things that your headings are, so after the person did that I'd say now write all your information down in the right heading and after that I'd say you compared"(4:6-9).

Note that in the first example the student is not as involved saying that the classmate could copy the work missed. However, in the second example, the student is providing explicit instruction. Table 19 records the number of times students showed autonomy by not relying on notebooks, a friend or teacher to aid in their explanation of a problem

Table 19
Frequency of Subjects Per Grade Showing Autonomy*

Teaching Environment				
Interview Question	Grade 4 (n=22)	Grade 5 (n=23)	Grade 6 (n=19)	Total (n=64)
Content				
Interview 1 How would you teach favourite lesson?	20	19	13	52
Interview 2 How would you teach experiments?	9	13	6	28
Interview 3 - Part 1 How would you teach solar system?	16	11	7	34
Problem Solving				
Interview 3 - Part 2 How would you teach comparing?	18	18	15	51
Interview 4 - Part 1 How would you teach comparing?	22	23	18	63
Interview 4 - Part 2 How would you teach other skill?	21	23	16	63

*Criterion: no mention of worksheets or notes given by teacher to aid explanation

solving skill. The table is organized under the two headings, content and problem solving. Under each heading, the interview and question asked are given, accompanied by number of responses per grade along with the total.

Referring to Table 19 the distribution of responses across the grades is evenly distributed. Except for Interview 1, there is an increase in student autonomy as students progress through the teaching lessons. For Interview 1, the students were asked to talk about a favourite lesson. Several students talked about gym, art and music and in these situations they talked about using equipment or objects. The equipment or objects used were counted as equipment such as balls, paint brushes or musical instruments are necessary for explanation in these subjects. Note in each part of Interview 4, 63 students (98%) did not refer to any outside resources as they explained how to perform the skill in question.

A difference to note in Table 19 is the response related to content for Interview 3, Part 1 compared to the response related to problem solving for Interview 3, Part 2. Thirty-four students (53%) displayed autonomy while explaining the solar system yet at the same interview when talking about the problem solving skill 51 students (80%) who were able to display autonomy. From this observation, a conjecture to be made is that procedural knowledge may be easier to learn related to problem solving rather than content. The content for the solar system was taught in a problem solving context yet students appear to be more autonomous or self-directed with procedural knowledge about a problem solving skill rather than content.

A Chi-square test was conducted to determine if there were any significant patterns related to students using notebooks or outside resources in their explanations of how to

compare. Using results for procedural knowledge from Table 19, Interview 3, part 2 and Interview 4, part 1, when students were asked how they would teach the skill of comparing, no significant association was observed between the three grades and the two interviews (Chi-square = 1.19, $df = 2$, $p > 0.15$).

In conclusion, from the analysis of the data related to Question Two, procedural and conditional knowledge seem to develop extensively within a problem solving environment. Recall from Table 17, totalling content responses for three and two interviews, 3 students (5%) provided step by step explanations whereas for problem solving 27 students (42%) provided step by step explanations. For conditional knowledge, referring to the same interviews, for content, 5 students (8%) applied skills to real life situations whereas for problem solving, 62 students ((97%) applied the skill they had learned to a real life context. While not as extensive, there is also an increase in declarative knowledge from 17 students (26%) who presented information in an ordered fashion in the interviews related to content as opposed to 36 students (56%) who presented information in an ordered manner in the problem solving context. Thus the following research question arises. Does the problem solving environment provide a more integrated approach to learning declarative, procedural and conditional knowledge? The results of the present study, while limited, give evidence that the problem solving teaching context has enhanced the learning of declarative, procedural and conditional knowledge possibly by providing more meaningful associations and connections which have facilitated learning.

Response Three: Relationship Between Declarative and Procedural Knowledge

The literature on declarative and procedural knowledge makes a distinction between the cognitive processing of the two types of knowledge (Anderson, 1983; Derry, 1990;

Newell, 1989). Declarative knowledge has been characterized as knowing what and procedural knowledge as knowing how. Is there a relationship between knowing what and knowing how? In order to estimate the level of relationship between factual information and performance of a task, student responses for declarative and procedural knowledge from the second set of questions from Interview 3 and the two sets of questions from Interview 4 will be analysed.

For declarative knowledge, the first question in Interview 3, Part 2 asked the students to tell what they knew about comparing. Then for procedural knowledge in the same interview the students were asked how they would teach or tell how to compare. After four months in Interview 4, Part 1 they were asked to tell what they knew about comparing again and also how they would teach the skill. In the second part of the same interview, they were asked to choose another skill they had learned and tell what they knew about that skill and then, how they would teach or tell about the skill in question. While some students presented their knowledge of skills in an ordered way for declarative knowledge, further patterns were exhibited. There was a difference in the definitions. While some gave the meaning of the skill, others included in their definition the actual steps to follow in the process. Criteria were thus established for a precise definition and an imprecise definition. The criterion for a precise definition was that the steps used in comparing followed the framework of Induction (Holland et al. 1986); collecting information, analysing information and forming conclusions. The criterion for the imprecise definition was that the students showed an understanding of the term but they did not specifically refer to all the steps in the Holland et al. (1986) framework. And if a student did not meet either criterion the response was recorded as other.

Table 20 provides examples of and criteria for precise and imprecise definitions, along with precise and imprecise explanations related to the skill of comparing. The table gives responses from three students which show three combinations. The first, gives a precise definition and a precise explanation, the second, gives an imprecise definition and a precise explanation and the third, gives an imprecise definition and an imprecise explanation.

Referring to Table 20, note that in the first example of a precise definition and precise explanation all the steps in the Holland et al. (1986) framework of Induction are cited. For the precise definition, the student talked about obtaining facts, then putting them in categories and making the comparison. Then for the precise explanation the student spoke of establishing the categories, getting facts and then deciding whether the planets were the same or different.

In the second example, for the imprecise definition the student talked about finding out which story was better indicating an understanding of comparing but made no mention of collecting information, analysing information or forming conclusions. Yet, when asked how to compare the student gave a precise explanation. Reference was made to conducting research, putting the information in boxes on green or white sheets, comparing and deciding what to do. Note the white and green boxes were used for teaching an organizational structure for the skill of researching.

In the third example, the student definition of comparing was recorded as imprecise. Reference was made to two objects and seeing "what they each have", therefore the student gave evidence of knowing the meaning of comparing. Also, the explanation was also recorded as imprecise because reference was made only to the use of the science

Table 20

Examples of Precise and Imprecise Definitions and Explanations
for Declarative and Procedural Knowledge

Precise Definition (3:6-4 Part 2)*

"when you are comparing you need two different, two or more different things to compare and you need facts to learn about them, put them in different categories and then we compare if they are different, they're unique or they're the same like in a way that's probably it"

Precise Explanation (3:6-4 Part 2)

"you tell them it's not hard for one thing and all they had to do was do the two planets or whatever they had to do comparing... I am going to tell them if we've been assigned categories we can put them in like alphabetical order or however you want them and then you would get some facts about them and make sure they put them in the planet they found them in tell if they are finished with that category they just go to the bottom and figure out whether its the same, different and unique"

Imprecise Definition(4:4-9 Part 1)

"it is when you find out either what is better or what you would like to do, like if you would like to read a story and you don't know which one, you can kind of compare which one is better"

Precise Explanation (4:4-9 Part 1)

"I'd find two things to compare and I'd tell them to do research on one and when they are done that one, do research on the other and then when you are done the research, what they know, what they already knew about things like put down on green sheets in boxes and what they learned they could put down on white sheets and they could compare like sheets and see which one is better or what they would like to do"

Imprecise Definition (3:6-14 Part 2)

"well its a comparison between two topics or objects you are comparing which, like what they have"

Imprecise Explanation (3:6-14 Part 2)

"well first I'd teach him what comparing is and I would use my materials... well my science book I'd let him borrow it to catch up on the work that we're doing in comparing cause that's all the write up that we did on comparing it's in the science book"

*(3:6-4) refers to interview 3: grade 6 - student 4

notebook. Note that in this example, in both the imprecise definition and the imprecise explanation, the components of the Holland et al. (1986), collecting information, analysing information and forming conclusions were not identified.

The relationship between declarative and procedural knowledge is recorded in Table 21. For declarative knowledge, the first question in Interview 3, Part 2 asked the students to tell what they knew about comparing. Then for procedural knowledge in the same interview, the students were asked how they would teach or tell how to compare. After four months in Interview 4, Part 1, they were asked to tell what they knew about comparing again and also, how they would teach the skill. In the second part of the same interview, they were asked to choose another skill they had learned and tell what they knew about that skill and then, how they would teach or tell the skill they had selected to talk about. The purpose of the interviews was to know whether students could define a skill and outline the steps in the performance of a problem solving task using the Holland et al.(1986) problem solving framework. The responses showed that some students outlined the steps in the declarative knowledge format while others did so in the procedural knowledge format. From the responses two questions arise. First, how many students can identify the steps in the Holland et al. (1986) framework whether they identify them in the declarative knowledge task or the procedural knowledge task? Second, do any patterns emerge which identify a relationship between declarative and procedural knowledge? For example, if a student outlines the steps in the Holland et al. (1986) framework in the declarative knowledge format does it follow that the student will do so in the procedural knowledge format? To determine whether there is a relationship between the two types of knowledge, responses to the three interviews were analysed using the following categories: Precise Definiton/Precise Explanation, Imprecise Definition/Precise

Table 21

Number of Subjects Per Grade Meeting the Criterion for Explanations Related to Declarative/Procedural Knowledge in Problem Solving*

Interview				
D - Declarative Knowledge Question	Grade 4	Grade 5	Grade 6	Total
P - Procedural Knowledge Question	(n=22)	(n=23)	(n=19)	(n=64)
Declarative/Procedural Knowledge Responses				
Interview 3, Part 2				
D - Tell what you know about comparing.				
P - How would you teach comparing?				
Precise Definition/ Precise Explanation	2	3	3	8
Imprecise Definition/Precise Explanation	3	10	3	16
Precise Definition/Imprecise Explanation	1	1	1	3
Imprecise Definition/Imprecise Explanation	10	5	8	23
Other	6	4	4	14
Interview 4, Part 1				
D - Tell what you know about comparing.				
P - How would you teach comparing?				
Precise Definition/ Precise Explanation	2	6	1	9
Imprecise Definition/Precise Explanation	7	4	5	16
Precise Definition/Imprecise Explanation	0	0	0	0
Imprecise Definition/Imprecise Explanation	11	12	13	36
Other	2	1	0	3
Interview 4, Part 2				
D - Tell what you know about selected skill.				
P - How would you teach selected skill?				
Precise Definition/ Precise Explanation	5	2	2	9
Imprecise Definition/Precise Explanation	8	13	7	28
Precise Definition/Imprecise Explanation	0	0	0	0
Imprecise Definition/Imprecise Explanation	7	4	10	21
Other	2	4	0	6

*Criterion: **Precise Definition** and **Precise Explanation** refer to collecting information, analysing information and forming conclusions.

Explanation, Precise Definition/Imprecise Explanation and Imprecise Definition/Imprecise Explanation.

Referring to Table 21, note the similarity in the number of students at all three interviews, 8 students, 9 students and 9 students respectively, who were able to give precise definitions and precise explanations. Interesting is the number of students who gave imprecise definitions but precise explanations. The precise explanation shows that these students knew the problem solving steps in the Holland et al. (1986) framework despite not referencing them in their definition. Possibly they did not realize that it was necessary to outline the steps in performing a problem solving skill when defining the skill. At Interview 3, Part 2 and Interview 4, Part 1, 16 (25%) students on both occasions gave such a response, while 28 (44%) students did so at Interview 4, Part 2. The increase at this last interview may be attributed to choice. Students were able to choose the skill they wished to talk about and likely would choose the skill they knew well. Note the number of students in all three interviews who gave imprecise definitions and imprecise explanations, 23 students (36%), 36 students (56%) and 21 students (33%) respectively. It appears that if the student cannot tell what, then he/she has difficulty telling how. In addition, further support for the apparent relationship of declarative and procedural knowledge is the few students who gave a precise definition and an imprecise explanation, 3 students, 0 students and 0 students respectively.

For each of these three interviews a Phi-coefficient was computed to test whether there exists a relationship between the degree of precision in the definition of a problem solving skill and the degree of precision in the explanation of how to perform that skill. The results are recorded in Table 22. Referencing Table 22, the coefficients vary between .32 and .49. Using a Chi-square statistic the three Phi-coefficients were found to be

Table 22

Relationship Between Declarative and Procedural Knowledge
for each of Interview 3, Part 2 and Interview 4, Part 1 and 2

Interview	Definition	Explanation		Phi Coefficient	Chi Square (df=1)
		Imprecise	Precise		
Interview 3 Part 2	Precise	3	8		
	Imprecise	23	16	.464	8.63**
Interview 4 Part 1	Precise	0	9		
	Imprecise	36	16	.490	11.99**
Interview 4 Part 2	Precise	0	9		
	Imprecise	21	28	.323	4.33*

* $p < 0.05$

** $p < 0.001$

significant at the .05 level of significance. These results indicate that there is a significant relationship between the degree of definition of a skill and its degree of explanation.

The number of students who identified the steps in the Holland et al. (1986) framework has been recorded for each of the three interviews in Table 21. However, the table does not indicate the number of students who can actually identify the steps on at least one occasion. The identification of this number of students is important because it is an indicator that the student knows the problem solving steps but perhaps has not internalized the process sufficiently to relate it to all instances. A survey of the charts, established from the codes, Tables 8 and 9, shows that the number of students who can identify the problem solving steps on at least one occasion are: Grade 4, 18 students (82%), Grade 5, 21 students (91%) and Grade 6, 13 students (68%). To summarize, these numbers show that an average of 80% of the students can identify the steps in problem solving, that is the components of the Holland et al. (1986) framework of Induction.

Bellanca, (1990,1992) and Black and Black, (1990) stress that a critical component of thinking is the organizing of information. The organizing of information is the second step in the Holland et al. (1986) framework. A question to be asked is whether or not students were able to identify the need for an organizational structure, despite not being able to articulate a precise definition or a precise explanation. An example of such a response in Interview 4, Part 1, for the declarative knowledge question when the student was asked to tell what he/she knew about comparing was: "well I know how to first, like do what you need to have, what you need to find out you have to try to organize it and on a chart or in a great way and then you have to do it like you have to make your decision" (4:4-7). Then an example of a response from the same interview for procedural knowledge when the student was asked how to teach a friend how to compare was: "probably teach

them like, I'd tell them, like i'd tell them, like I'd let them pick two places if they wanted and I'll ask them what's the same and what's different, like you can put them in categories" (4:5-29). In summary the responses from these students, while not clear, show that they did identify the need for an organizational structure. The first student talked about trying to organize on a chart while the second talked about putting the places in categories.

Table 23 identifies the number of students who were able to show the need for an organizational structure in a problem solving context. The table is organized according to the three interviews. Under each interview heading, the declarative and procedural knowledge questions are given, as in either question the student could mention the need for an organizational structure.

Referring to the total responses for each of the three interviews in Table 23, 48 students (75%), 50 students (78%) and 55 (85%) respectively, recognized the need for an organizational structure. While not meeting the criterion for a precise definition or a precise explanation, a large number of students have internalized the need for organized networks within the cognitive system (Derry, 1990).

Because such a large percentage of students recognized the need for an organizational structure while not meeting the criteria for precise and imprecise definitions, it is important to identify the percentage of students who recognized the need on more than one occasion. Table 24 records the number of occasions in which the students identified the need for an organizational structure. Under each numbered interview, the table gives the interview questions. Listed under the questions are the number of students per grade and the total who recognized the need at three, two, one or no interviews.

Table 23

Number of Students Per Grade Meeting Criterion
for Organizational Structure in Problem Solving

Interview**D - Declarative Knowledge Question/**Grade 4
(n=22)Grade 5
(n=23)Grade 6
(n=19)Total
(n=64)**P - Procedural Knowledge Question****Interview 3 - Part 2****D - Tell what you know about comparing/****P - How would you teach comparing?**

13

21

14

48

Interview 4 - Part 1**D - Tell what you know about comparing/****P - How would you teach comparing?**

14

18

18

50

Interview 4 - Part 2**D - Tell what you know about selected skill/****P - How would you teach selected skill?**

17

21

17

55

*Criterion: identification of the need for an organizational structure

Table 24
Number of Occasions Subjects Per Grade Meeting
Criterion for Organizational Structure

Interview				
D - Declarative Knowledge Question				
P - Procedural Knowledge Question				
Number of Interviews	Grade 4 (n=22)	Grade 5 (n=23)	Grade 6 (n=19)	(Total) n=64
Three Interviews	9	17	13	39
Exactly Two Interviews	7	4	5	16
Exactly One Interview	5	1	1	7
No Interview	1	1	0	2

*Criterion: identification of the need for an organizational structure

Note to the Table:

Interview 3 - Part 2

D - Tell what you know about comparing.

P - How would you teach comparing?

Interview 4 - Part 1

D - Tell what you know about comparing?

P - How would you teach comparing?

Interview 4 - Part 2

D - Tell what you know about selected skill.

P - How would you teach selected skill?

Referring to Table 24, 39 students (61%) identified the need for an organizational structure at all three interviews. Then 16 students (25%) identified the need at two interviews, 7 students (11%) at one interview leaving only 2 students (3%) who never identified the need for an organizational structure. These results are encouraging as they provide support for the work of Bellanca (1990, 1992) and Black and Black (1990) in their designs of organizational frameworks for instructional purposes.

To summarize, the results show that there is a relationship between declarative and procedural knowledge. Referring to Table 21, for the three interviews from the problem solving context, few students, 3, 0 and 0 respectively, gave an imprecise explanation after they had given a precise definition. And, it could be assumed that those students who did give a precise explanation but not a precise definition were unaware that they needed to be more explicit in their definition. Further evidence from Table 21, to show the relationship of the two types of knowledge, is the high number of students who gave an imprecise definition followed by an imprecise explanation. That is, when they did not know the meaning of comparing they could not tell how to do it. However, despite the newness of the problem solving teaching orientation, the students have recognized the need to organize or analyse information. Recall from Table 24 that 62 students out of the 64 (98%) recognized the need for an organizational structure on at least one occasion and over half of the students (61%) recognized the need on all three occasions.

Response Four: Recall of Information

Important to instruction is the management of memory (Glaser & Pellegrino, 1987). These authors claim that memory is dependent on knowledge of content and knowledge of process. Therefore, and in accord with Eylon and Reif (1984) and Heller and Reif (1982),

in order to facilitate recall, instruction must emphasize the explicit teaching of problem solving skills. In the present study, problem solving skills were taught explicitly using the components identified in problem solving models, collecting information, analysing information and forming conclusions (Bransford & Stein, 1992; Holland et al., 1986; Isaksen & Treffinger, 1985; McPherson, 1977).

In order to examine student recall following the explicit instruction of the problem solving skill of comparing, students were interviewed on two occasions. First for declarative knowledge, the students were asked, in Interview 3, Part 2, to tell what they knew about comparing. After a four month period, they were asked the same question again in Interview 4, Part 1. Responses were recorded as ordered or random. A response was deemed ordered whenever the student identified the meaning of comparing using ordered or connected statements. A random response showed no sequence or flow of facts. Whenever the response was incorrect or the student said that he/she did not know the answer it was coded as other. Using these criteria, patterns of recall were identified.

Table 25 provides examples of responses and criteria for Interview 3, Part 2 and Interview 4, Part 1 where the latter was conducted four months later. Six combinations of responses are displayed. First, for declarative knowledge, a random and an ordered response are given. Second, for procedural knowledge, a global and a step by step explanation are provided and for conditional knowledge, real life situation responses are recorded. From Table 25 for declarative knowledge, the random response did not indicate whether the student knew about comparing. The statements showed no connection, whereas on the second occasion the student made reference to looking at two things then followed through the statement by saying whether they would be the same or different.

Table 25

Patterns of Recall for Declarative, Procedural and Conditional
Knowledge from Interview 3 and Interview 4

Declarative Knowledge - Random Response (3:4-15)

"you can compare many things you can write a note on comparing what you have compared"

Declarative Knowledge - Ordered Response (4:4-15)

"it is when you take two things and look at them and see if they're the same or if they're different"

Procedural Knowledge - Global Response (3:5-9)

"I'd maybe do a little comparison for them just a little one for them maybe compare two people and then I'd compare ask them to compare another two people two different people so I could like mark them to see if they still are stumbling on it or pick it up"

Procedural Knowledge - Step by Step Response (4:5-9)

"well you get him to pick two things that two things that he's interested in so that he can compare them then you tell him to get some categories and you can help him if he can't find any about the two things or places then you say tell ask him to find differences in the categories for the two things of places or whatever and then after he's done the differences the similarities"

Conditional Knowledge - Real Life Situations (3:5-29)

"I'll pick houses I guess well like if you are going to be buying a house you don't want to just pick one the first one that you see because it could be stuff wrong with it or something and I think like you should pick like two or three houses and then figure out which one has say you are somebody that likes land has the most land whether it is the least expensive but still really good and stuff like that"

Conditional Knowledge - Real Life Situations (4:5-29)

"well if you had to get a job or something and you wanted to get a certain job and there were two places that you could get it you could compare things like that people how nice they are what rules they have if you like the rules of each place what the pay is what you get for stuff"

Second, for procedural knowledge, the students were asked in Interview 3 how they would teach or tell a person how to compare. They were asked the same question, after a four month period, in Interview 4. A response was recorded as a step by step response when the student followed a systematic explanation using the components of Induction, collecting information, analysing information and forming conclusions (Holland et al. 1986). Otherwise, responses were recorded as global. If a student said that he/she did not know the answer, it was identified as Other. From Table 25, for procedural knowledge, in the first instance, the student was not telling how to compare but the second time the procedure was given. Mention was made of taking two things, getting categories and looking at similarities and differences.

Third, knowing when to use a skill, or conditional knowledge, is also dependent on how well an individual remembers the skills taught. The importance of teaching for application or transfer has been identified by Bransford et al. (1992), Greeno (1990), Heller (1983), Holyoak (1990), Perkins and Salomon (1988) and Reif (1987). In the present study, students were taught the skill of comparing in a way that provided opportunities for them to be aware of its flexible use. In the third question Interview 3, Part 2, the students were asked when they could use comparing again. Then, in Interview 4, Part 1, after the four month period, they were asked the same question. Responses were recorded as related to real life situations or to school subjects. Referring to Table 25, for conditional knowledge, both responses show the student applying the skill in out of school situations, first, buying a house and second, looking for a job.

The frequencies of patterns of recall for declarative, procedural and conditional knowledge from Interview 3 and Interview 4 after a four month period are recorded in Table 26. The table is organized according to the three types of knowledge, declarative,

Table 26

Patterns of Recall Across Grades for Declarative, Procedural and Conditional Knowledge from Interview 3 and Interview 4

Type of Knowledge Question Pattern of Recall	Grade 4 (n=22)	Grade 5 (n=23)	Grade 6 (n=19)	Total (n=64)	Phi Coeff.
Declarative					
Tell what you know about comparing.					
Ordered to Ordered	5	6	3	14	0.009
Ordered to Random	1	4	3	8	
Random to Ordered	4	7	9	20	
Random to Random	6	3	2	11	
Other	6	3	2	11	
Procedural					
How would you teach comparing?					
Step by Step to Step by Step	5	4	4	13	0.130
Step by Step to Global	1	9	4	14	
Global to Step by Step	4	6	2	12	
Global to Global	11	3	8	22	
Other	1	1	1	3	
Conditional					
When could you use comparing again?					
Real Life Situations to Real Life Situations	20	17	15	52	0.088
Real Life Situations to School Subjects	1	3	1	5	
School Subjects to Real Life Situations	1	1	3	5	
School Subjects to School Subjects	0	0	0	0	
Other	0	2	0	2	

*Criteria: **Declarative** - ordered responses must refer to meaning of comparing with statements showing a connection to previous fact given. **Procedural** - step by step response must identify all components of Induction, collecting information, analysing information and forming conclusion. **Conditional** - use for comparing given other than school subjects.

procedural and conditional knowledge. For each pattern of recall, the frequency of responses per grade and for the total are provided. This information is followed by the reporting of the Phi-coefficient computed from the pattern totals.

Referring to Table 26, the frequencies of responses are similar across the grades. For declarative knowledge, there were 53 paired responses that were used for the analysis of recall. They were; ordered to ordered(14), ordered to random (8), random to ordered (20) and random to random (11). Using the paired responses, 34 (14 plus 20) students (64%) gave ordered responses at Interview 4. Of those 34 students, 14 students gave an ordered response initially but 20 students (59%) changed from a random response to an ordered response at Interview 4. Nineteen (8 plus 11) of the students gave random responses at Interview 4. Eleven of these students gave random responses at Interview 3, however 8 students moved from an ordered response to a random response at Interview 4. Looking at the initial responses in relation to the responses at Interview 4, 22 (14 plus 8) students (42%) gave an ordered response initially. At Interview 4, 14 of those students continued to do so while 8 students gave a random response. Thirty-one students (20 plus 11) began with a random response with 11 of those students continuing to give a random response at Interview 4. However 20 students (65%) changed to an ordered response at Interview 4.

To be highlighted for recall of declarative knowledge is the 20 students who moved from giving a random response at Interview 3 to an ordered response at Interview 4. Not only did they remember the skill of comparing but were able to define it in a manner which met the criterion for ordered presentation of knowledge. This result suggests that the cognitive networks of these students are becoming structured. Note that over the four month period, between Interview 3 and Interview 4, students were taught other step by

step procedures in order to perform other problem solving skills as research, seeing relationships, ordering and finding the central idea. Thus, the increase supports the work of Glaser and Pellegrino (1987), who say that the improvement of the skills of learning will take place through the exercise and development of the management of memory, knowledge representation and problem solving procedures.

Referring again to Table 26, for procedural knowledge, there were 61 paired responses meeting criteria that could be used for analysis. They were; step by step to step by step (13), step by step to global (14), global to step by step (12) and global to global (22). At Interview 4, 25 (13 plus 12) students gave step by step explanations. Of those 25 students, 13 had given a step by step explanation initially. However, 12 students changed from a global response at Interview 3 to a step by step explanation at Interview 4. Thirty-six (14 plus 22) students gave a global response at Interview 4. Twenty-two of these students did not change, but 14 changed from giving a step by step response at Interview 3 to the global response at Interview 4. Initially, 27 (13 plus 14) students gave a systematic response at Interview 3 and 14 of these students changed to a global response at Interview 4. Yet, 13 students remained giving systematic responses at Interview 4. Thirty-four (12 plus 22) students first gave global responses but 14 of these students changed to a step by step explanation. However of the 34 students, 22 remained giving global responses.

Important to note is the number of students who initially gave global responses and then gave a systematic explanation four months later. For these students, the change supports the notion that student cognitive networks are becoming better organized, showing the benefits once again of continued explicit teaching of problem solving skills (Eylon & Reif, 1984; Glaser & Pellegrino, 1987; Heller & Reif, 1982). However, for the students who moved from a step by step to a global response (14), and for those students

who gave a global response on both occasions (22), the explanation may be that their cognitive networks are not sufficiently organized. White (1993) stresses the importance of the length of time of instruction in the management of memory. For the students who could not provide step by step explanations at Interview 4, the length of instruction in a problem solving context may not have allowed sufficient time for their cognitive networks to be as organized.

Referring further to Table 26, for conditional knowledge, there were 62 paired responses from which the analysis could be conducted. They were; real life situations to real life situations (52), real life situations to school subjects (5), school subjects to real life situations (5) and school subjects to school subjects (0). At Interview 4, 57 (52 plus 5) students (91%) gave a real life situation response. Of those 57 students, 52 students did not change their responses while 5 students moved from giving a real life situation response to a school subjects response. Referring to the responses at Interview 3, 57 (52 plus 5) students gave a real life situation response with 52 of those students continuing to do so at Interview 4. Five students began with school subject responses and changed to real life situation responses. No students began with a school subjects response and ended up giving the same type of answer at Interview 4.

To be highlighted for conditional knowledge is that 52 students continued to apply the skill of comparing to real life situations after four months. Results are in accord with Bransford et al. (1992), Greeno (1990), Heller (1983), Holyoak (1990), Perkins and Salomon (1988) and Reif (1987). They advocate the use of a teaching framework or structure which is flexible and sufficiently abstract to encompass its use in a variety of situations. Such was the lesson structure for the teaching of comparing. Note that in the

lessons, the students were taught as a class, how to develop a comparison chart. They were given opportunities in groups and individually to use the chart in other contexts.

From Table 26, the most important observation was the increase in students who, for the declarative and procedural knowledge questions, responded in a random to ordered or global to step by step manner. According to the literature (Glaser & Pelligrino, 1987), these results indicate that student cognitive networks are becoming more organized, facilitating recall of information. Students must be given help to integrate their accumulating knowledge in a coherent structure facilitating flexible use (Reif, 1987). In each of the problem solving contexts an organizational structure had been introduced to the students (Black & Black, 1990) which led to more organized recall of information. For conditional knowledge, a large number of students (84%) continued to apply their knowledge to real life situations after the four month period. Chi (1987) cites the identification of a goal as being important for transfer or application of knowledge. The students in each of the problem solving teaching contexts were seeking to solve a problem, thus a goal had been identified. Thus, goal identification in the teaching context may be attributed to the high frequency of real life situation responses for conditional knowledge.

The results of the Phi-coefficient showed there was not significant relationship between recall of declarative, procedural and conditional knowledge when comparing Interview 3 and Interview 4.

Summary of Results

In summarizing the Results chapter, it appears that content can be effectively taught in either a content environment or a problem solving environment. However, there is a

strong indication that the problem solving environment enhances the learning of problem solving skills. These skills include declarative, procedural and conditional knowledge which, according to the results of the study, appear to be related. First, a relationship between declarative and procedural knowledge was observed. A large number of students could not tell how to perform a skill (procedural knowledge) when they could not define the skill (declarative knowledge). However, the responses of these students showed that they recognized the need to organize or analyse information which is the main difference between the two teaching environments. In the problem solving environment, the students were taught explicitly how to use graphic organizers to interpret the information they had collected whereas in a content environment, the assumption usually is made that students will make the appropriate interpretations implicitly.

Second, the teaching of conditional knowledge, along with declarative and procedural knowledge, has been shown to be important. Results demonstrate that students can identify real life situations where the skill in question may be applied. Because of the complementarity of declarative, procedural and conditional knowledge, it would be advantageous to teach the three types of knowledge in conjunction with one another. The sequencing of skill development provided in a problem solving approach allows for such teaching. In a problem solving approach, students collect information (declarative knowledge), organize the information (procedural knowledge) and then reach a solution or form a conclusion (conditional knowledge).

Despite the newness of the problem solving orientation for the students in the study, there is evidence of their continued growth in problem solving expertise. Specifically, there was an increase in the number of students who initially gave random or global responses about the skill of comparing and then, four months later, gave ordered or

step by step responses. Likewise, the continued growth is shown with the increase in students meeting the criteria for ordered, step by step and real life responses at the last interview.

Where applicable, the Chi-square analysis was conducted. First, the analysis showed no level of association between grade level and knowledge acquisition. This finding provides support to regroup the students across grades. Second, a relationship (Phi-coefficient) was shown between declarative and procedural knowledge which supports the work of Holland et. al (1986) and Glaser and Pellegrino (1987). From the observed relationship, problem solving environments form an important structure for teaching declarative and procedural knowledge. Third, there was no significant relationship (Phi- coefficient) between recall of declarative, procedural and conditional knowledge when comparing Interview 3 and Interview 4.

To the knowledge of the researcher, the curriculum written for the present study was an innovative use of the Holland et al. (1986) framework of Induction to integrate the teaching of declarative, procedural and conditional knowledge. The Discussion chapter provides further comments on the use of the Holland et al. (1986) framework to provide a simplified structure for curriculum design.

CHAPTER SIX

DISCUSSION

The study was designed to explore the knowledge acquired by students following instruction in two teaching environments, one with a content orientation, the other with a problem solving orientation. The key components of problem solving, collecting information, analysing information and forming conclusions, were identified through the work of McPherson (1977), Bransford and Stein (1992), Bransford et al. (1987), Isaksen and Treffinger (1985) and Eggen et al. (1979). These components also appear in the Holland et al. (1986) framework of Induction. The Holland et al. (1986) framework was used as the theoretical base for the present study. Skills of collecting information, analysing information and forming conclusions were explicitly taught in the problem solving environment. In the content orientation, the focus was on content with the underlying assumption that students implicitly would learn problem solving skills.

Three types of knowledge are generally accepted. They are; declarative, procedural and conditional knowledge (Anderson, 1983; Marzano et al., 1988). Declarative knowledge is characterized as knowing what, procedural knowledge as knowing how and conditional knowledge as knowing when. These concepts are related to the components of the Holland et al. (1986) framework of Induction. Collecting information is related to knowing what information is needed, analysing information is related to the procedural knowledge needed to perform the task and forming conclusions is related to when and where the information should be used. For the present study, the relationship between the two sets of terms was confirmed by eight judges. These judges selected, from a large group of questions, the questions which best represented a correspondence between

declarative knowledge and collecting information, procedural knowledge and analysing information and conditional knowledge and forming conclusions. In addition, Paris and Winograd (1992) identify declarative, procedural and conditional knowledge as the three types of knowledge used to communicate metacognitive processing. They state that students are displaying metacognitive skill if they can verbalize declarative, procedural and conditional knowledge in relation to a problem. The research design incorporated interviews as the main source of data collection. Therefore, using the work of Paris and Winograd (1992), in each interview, students were asked to respond to a declarative, procedural and conditional knowledge question. In this context four research questions emerge.

Question One: Do the characteristics of the three types of knowledge, declarative, procedural and conditional knowledge, differ between the content environment and the problem solving environment? Critics say that educators must change their role from information based teaching to problem solving skills teaching (Brandt, 1993; Voss et al. 1991). Therefore the question is important in order to determine whether or not the skills needed to solve problems will be enhanced with the increased emphasis on the systematic teaching of problem solving skills rather than an emphasis on acquiring information.

Question Two: Do students in the problem solving environment show more consistency in their responses to the declarative, procedural and conditional knowledge questions? It is important to note whether or not students will be able to show expertise in problem solving skills on more than one occasion.

Question Three: Is there a relationship between declarative and procedural knowledge? From the Review of the Literature declarative knowledge has been

characterized as knowing what and procedural knowledge as knowing how. It should be noted that the relationship between declarative and procedural knowledge will be assessed from information extracted from interviews and not by observation of task performance. The relationship could be qualified as "perceived relationship".

Question Four: After a four month period, to what extent do students recall information, the declarative, procedural and conditional knowledge, that they learned in the problem solving teaching environment? An important prerequisite for transfer or application of skills is whether or not the individual remembers the skills learned.

In the Results chapter, empirical evidence was presented in response to the four research questions. In the present chapter, each response will be discussed in relation to current educational practices and theory. Suggestions for future research, limitations of the study and conclusions follow. The chapter concludes with educational implications highlighting the value of the study to meet the requirements of present day curriculum writing.

Response One: Knowledge Characteristics

There is a difference in the knowledge characteristics displayed by the students when they had been taught in a content environment and a problem solving environment. An overview of the knowledge characteristics shows that they met the criteria for declarative, procedural and conditional knowledge more in the problem solving teaching environment. For declarative knowledge, their responses were more ordered, for procedural knowledge they gave more step by step explanations and for conditional knowledge they related their acquired knowledge more to real life situations. The content

taught in a content environment or in a problem solving environment seems to produce the same learning effect for declarative, procedural or conditional knowledge. But, it seems that problem solving skills are enhanced by the systematic teaching of declarative, procedural and conditional knowledge in relation to these skills. In addition, while some students did not meet the criteria for ordered or systematic explanations, they recognized the need for an organizational structure to analyse the information collected in order to solve a problem. Another pertinent observation was the number of students who recalled the problem solving skill that had been taught after a four month period. In the interim, students were taught other problem solving skills but were able to maintain their knowledge of the first skill taught.

What has been demonstrated in the present study is that an emphasis on content instruction, with the assumption that students will learn problem solving skills implicitly, is not as effective as the explicit teaching of problem solving skills in a problem solving teaching environment. When students were asked how they would teach or tell about the content they had learned, their responses were not systematic or step by step explanations. However, responses related to a problem solving skill, showed that the students knew the step by step procedures for solving the problem in question. Furthermore, they were able to give real life examples of when they would use the skill again. From the Review of the Literature, advocates of problem solving skills teaching environments suggest the integration of content with problem solving skills (Eggen et al. 1979, Glaser & Pellegrino, 1987). An interesting research question arises. What is the effect of the learning environment on the teaching of content? The present study, while limited, does suggest little effect on content knowledge whether students are taught in a content environment or a problem solving environment.

The results show there is a strong indication that the problem solving environment enhances the learning of problem solving skills. Heller and Reif (1982) and Swartz and Perkins (1989), believe that students must be taught explicitly problem solving skills within a problem solving context. Thus from the analysis of the present study and the beliefs of the forementioned theorists, the following research question begins to have particular importance. Does the teaching environment play a role in the learning of problem solving skills? Highlighted in The Common Curriculum (1993) is the need to teach problem solving skills but there is no reference to any specific teaching environment. Based on the experience of the researcher, current trends in education promote environments which emphasize cooperative learning, discovery learning, child centered learning or activity based learning. The usual emphasis in these environments is on content learning with the underlying assumption that students will learn problem solving skills implicitly. From the results of the study and present teaching experience of the researcher, the primary focus should be on a problem solving environment which explicitly teaches problem solving skills. The Holland et al. (1986) framework of Induction has been shown to be useful in designing such a problem solving teaching environment. Then, incorporated into this environment may be situations which promote cooperative learning, discovery learning, child centered learning or activity based learning.

Response Two: Content Versus Problem Solving

After students had been taught in the content environment their responses were related to those responses recorded after they had been taught in the problem solving environment. The analyses showed that students met the selected criterion more often in the problem solving environment. For declarative knowledge, students produced ordered

responses more for knowledge about a problem solving skill than knowledge about the content they had learned. In relation to procedural knowledge, students demonstrated that they were able to articulate step by step explanations more often about a problem solving skill. What was most important in the comparison, was the display of student autonomy when students were explaining how to perform a problem solving task. When students had been taught in the content environment and were asked how they would teach a friend what they had learned they relied on their notebooks to help them with their explanation. While in the problem solving environment, when students were asked to explain the work, they relied on their own expertise or inner resources. There is evidence that they had better internalized the problem solving approach. Thus, the problem solving environment appears to lend itself to the acquisition of more student independence or self-direction, a goal identified by many educators over the years (Betts & Neihart, 1986; Issues and Directions, 1980; Rempel, 1986; Treffinger, 1981). Most recently, student independence is a principle underlying learning as stated in the Ministry of Education and Training, The Common Curriculum (1993).

Internalization of problem solving skills is further evidenced with conditional knowledge. In the content teaching environment, students said that they would apply what they had learned mostly to other school subjects, whereas, in the problem solving environment, their statement of further use referred mostly to real life situations. The results support the work of Bransford et al. (1992), Heller (1983), Holyoak (1990) and Reif (1987). These authors recommend problem solving teaching environments which encourage the flexible use of skills, that is, how skills may be used in a variety of situations. Consequently, skills must be taught with a level of abstraction which facilitates varied application.

Response Three: Relationship Between Declarative and Procedural Knowledge

The results show that there is an empirical relationship between declarative and procedural knowledge. From data analysis, it became apparent that if a student could not define a problem solving skill he/she could not tell how to perform the skill. Glaser and Pellegrino (1987) have identified the need to study both declarative and procedural knowledge. Most recently Royer, Cisero and Carlo (1993) stress the importance of both declarative and procedural knowledge in assessing student outcomes or products. Teaching environments thus have to focus on both declarative knowledge (knowing what) and procedural knowledge (knowing how). Perkins (1987), Heller and Reif (1982) emphasize the importance of teaching environments which explicitly teach problem solving skills in conjunction with content.

Another important outcome of the data analysis was student recognition of the need for an organizational structure in order to analyse information. Although some students did not meet the criteria for precise or step by step explanations of a problem solving skill, their answers reflected the need for an organizational structure. Perhaps the newness of the problem solving context did not allow sufficient instructional time for them to have the expertise in problem solving knowledge to meet the criteria for precise or step by step explanations. However, the success of the instruction was shown by students recognizing the need to organize or analyse information in a problem solving process. In contrast, in a content orientation, there is less assistance or explicit teaching of how to analyse information. Most often in a content teaching environment students are given various opportunities to collect information and reach conclusions. They are required to write reports, dramatize situations, illustrate happenings, but in most situations these tasks follow their collecting of information.

The importance of analysing or organizing information has been emphasized by Crane (1992). He stresses the need to ensure that students have levels of competency, stressing literacy and numeracy skills along with analytical tools to navigate in an information based society. Also, referring to the field of business, Rennie and Gibbins (1993), claim that experts, despite having their expertise organized in memory structures, require analytical tools or decision aids such as internal control guidelines, checklists and expert systems in order to use and adapt their expertise. Recognizing the importance of the need for individuals to have these analytical tools, Bellanca (1990, 1992) and Black and Black (1990) in their texts have developed frameworks for teaching students to organize and analyse information. However, caution is required as too many organizational frameworks may be confusing to students. What is important is the identification of the key organizers so that these structures can be taught and continually reinforced throughout the entire curriculum. Within the present study, organizational frameworks were introduced to teach the following problem solving skills, comparing, researching, finding relationships, ordering and finding the main idea. The results indicate that these structures could serve as a beginning to the selection of such organizational frameworks in the analysing of information stage in the problem solving curriculum (Holland et al. 1986).

Response Four: Recall of Information

The last interview was incorporated into the research design in order to identify whether or not students were able to recall, after a four month period, what they had learned. The last interview, conducted four months after the skill of comparing had been taught, showed more students responding in an ordered or systematic way than they had previously. The result is showing that student knowledge is becoming anchored within a

cognitive structure that facilitates retrieval. Within the four month period, students continued to be taught problem solving skills in a problem solving context. These skills were; researching, observing relationships, ordering and finding the central issue. A consideration is the length of time students are exposed to a particular teaching approach may increase expertise. White (1993) claims that a determining factor in recall is the duration of instruction, stating that the longer the instructional time period, the more likely the material is to be fixed securely in memory. In addition, Reif (1987) stresses the importance of systematic teaching to facilitate recall. For each of the problem solving skills, students were taught step by step procedures of how to perform the skill. In summary, the results of the last interview demonstrate that expertise further develops with continued teaching in a problem solving context.

Where applicable, the Chi-square analysis was conducted. First, the analysis showed no level of association between grade level and knowledge acquisition. This finding provides support to regroup the students across grades. Second, a relationship (Phi-coefficient) was shown between declarative and procedural knowledge which supports the work of Holland et. al (1986) and Glaser and Pellegrino (1987). From the observed relationship, problem solving environments form an important structure for teaching declarative and procedural knowledge. Third, there was no significant relationship (Phi- coefficient) between recall of declarative, procedural and conditional knowledge when comparing Interview 3 and Interview 4.

Future Research

Schools are being encouraged to teach problem solving skills in all subject areas and thus many resources are being produced which propose to teach such skills (Swartz &

Perkins, 1989, The Common Curriculum, 1993). From the teaching experience of the researcher, the result has been the production of many diverse programs which are leading to confusion among teachers. Referencing present day textbooks, Sternberg (1987) states they are unconnected bits of knowledge with skills often placed inappropriately within the text. Based on the results of a preliminary investigation to co-ordinate thinking skills, a curriculum was developed for the present study (Thinking Skills Consortium of Ontario, 1990). The curriculum is structured according to the Holland et al. (1986) framework of Induction and follows an explicit problem solving approach. The results provide evidence that the systematic approach undertaken enhances the learning and application of problem solving skills. More research to support the benefits of using such a simplified approach would be beneficial.

Throughout the study, organizational techniques to teach problem solving skills, comparing, researching, ordering, seeing relationships and finding the central idea were taught but always used under the Holland et al. (1986) framework. The results of the study showed that students identified a need to use an organizational framework to solve problems. Crane (1992) and Rennie and Gibbins (1993) have stressed the importance of the acquisition of analytical tools in order to use and adapt expertise. An important task for future researchers is the identification of common frameworks for the analysing information component of the Holland et al. (1986) framework that students will continue to use throughout their lives. Bellanca (1990, 1992) has identified twenty-seven, while Black and Black (1990) have identified eight. Included in their texts are frameworks similar to the ones used in the present study. Caution is needed as organizational frameworks, if too abundant, will create confusion and thus, lack of implementation.

The present study has explored the applicability of the Holland et al. (1986) framework of Induction to curriculum development in environmental studies. While the focus on the unit, Atmosphere and Beyond, was in environmental studies, some of the activities in the unit could have been linked to other subjects. For example, the legends studied for the work on the solar system could have been elaborated upon for English and the construction of the hot air balloons could have been a worthwhile activity for art. Using such an interdisciplinary approach, the goals for an integrated curriculum outlined in the Ministry of Education and Training, Towards an Integrated Curriculum (1993) could be achieved. Research could be conducted to evaluate such programming. Holland et. al (1986) in their text have referenced applications of their framework in the field of Science, Language and the Social Sciences. However, they encourage research to study the use of the framework in other areas. Included in the Ministry of Education and Training, The Common Curriculum (1993) as one of the core program areas is Self and Society. Thus a framework is not only needed in subject areas but in issues surrounding moral, social and emotional concerns.

The Chi-square analyses which showed no significant association between grade level and knowledge acquisition are conducive to current curriculum initiatives. A main initiative cited in the Ministry of Education and Training, The Common Curriculum (1993) is to encourage collaboration. Collaboration is encouraged in curriculum planning, in teaching and in the grouping of students. Consequently a school environment is encouraged where students and teachers are working together using a common curriculum. The results are encouraging for teachers who are hesitant to participate in the recommended initiatives because of the past demands of curriculum requirements at specific grade levels. As the study showed no significant association in the patterns of knowledge exhibited by students at the three grade levels, teachers may be more willing to group students at the

junior grade levels for more collaborative work. In addition, the stigma associated with mixed grade groupings may be lessened. Further research at other grade levels may produce similar results which then could support groupings of students in each of the primary, intermediate or senior divisions.

Critics of present learning environments which focus on content instruction claim that students lack the problem solving skills they require for the work force and everyday living (Schoen, 1990; Applebee, 1991; Schoenfeld, 1991; Voss et. al, 1991). Brady (1993), in an attempt to improve curriculum, suggests a core of content materials that relate to survival skills saying that current curriculum content has lost its meaning and relevance. Also, Ontario Ministry of Education, Transition Years (1993) and The Common Curriculum, Grades 1 to 9 (1993) have refined curriculum to four program areas referring only to ten elements of a common curriculum. Crane (1992) refers to the same movements to develop a common curriculum in other countries as he makes recommendations for education in the next century. However, the results of the present study show that there is little effect on content learning whether in a problem solving teaching context or a content teaching context. With the restructuring of content, research would be beneficial to evaluate the acquisition of content knowledge within problem solving teaching environments and content teaching environments.

Limitations of the Study

As reported, the study was designed for an environmental studies curriculum. Further research to evaluate the use of the Holland et al. (1986) framework of Induction in other subject areas is necessary and is recommended in light of the preliminary study involving the researcher of the present study (Thinking Skills Consortium, 1990). In

addition, the curriculum was implemented at the grade 4, 5 and 6 levels. Thus, in order for the framework to be a justifiable theoretical base for a common curriculum, studies need to be conducted to support its viability at other grade levels.

As the research was carried out at one school, although shown to be representative of a larger student population, studies conducted in other schools would continue to provide understanding of its applicability to education. One reason for the study being conducted at one school was a result of the specialized curriculum. Due to the unavailability of study units that followed the Holland et al. (1986) framework of Induction, curriculum had to be written. Working in one school reduced the complexities of organizing release time for teachers to write and implement the curriculum units.

Conclusions

Change begins in the classroom (Crane, 1992). As we approach the next century, Education at all levels must be our most important concern. The world competes on brainpower and technical knowledge. According to Crane (1992), our school systems have to adapt to the information revolution giving new priority to problem solving, critical thinking, how to analyse and synthesize and how to communicate as well as work in teams. Included as underlying principles in the Ontario Ministry of Education and Training working document, The Common Curriculum (1993), are the recommendations of Crane (1992). The principles incorporate collaborative teaching and learning, using methods that emphasize inquiry or problem solving in an integrated curriculum which is focussed in four program areas, Language, the Arts, Science and Technology and Self and Society.

The Holland et al. (1986) framework of Induction provides a problem solving approach to instruction. The framework allows for innovation or creative thinking because of its flexibility in the connections of ideas within the human cognitive system. The need for creative thinking in problem solving approaches has been stressed by Ennis (1987), Treffinger (1987) and Perkins (1988). And in accord with Vygotsky (1978), it incorporates the role of experience as an important component of the framework. Also, Holland et al. (1986) propose that the framework has a wide range of applicability. While the present study has explored its applicability to curriculum development in Environmental Studies or Science, results support the possibility of further research in other subject domains.

A coherent framework from which curriculum could be adapted or developed is an important beginning for the challenges in Education ahead. However, it should be noted that continued use of the Holland et al. (1986) framework of Induction by the author as a classroom teacher shows that the framework can be used with existing curriculum materials. Teachers need to recognize what aspects of their resource material deal with collecting information, analysing information or forming conclusions and then supplement, where necessary, to provide a problem solving approach for instruction. In summary, the Holland et al. (1986) framework is a tool for instructional planning which incorporates collecting information, analysing information and forming conclusions.

Educational Implications

A tabloid, Common Curriculum Highlights (1993), published to inform parents, students, taxpayers and all people interested in Education, outlines the differences between

the new curriculum and the old curriculum. One of the five differences cited is that problem solving is emphasized in all subject areas, not just in some as before.

The study has shown how a framework of problem solving can be applied to an educational setting. With the emphasis on three components; collecting information, analysing information and forming conclusions, the framework provides a simplified guideline for planning and writing curriculum. While the lesson units were specifically written for the study, teaching experiences by the researcher following the study confirm the work of the Thinking Skills Consortium of Ontario (1990), that the framework may be used with any curriculum requirements or teaching resources. Consequently, the new problem solving initiatives proposed by the Ministry of Education in The Common Curriculum (1993), may be incorporated using the Holland et al. (1986) framework of Induction. All that is required is the initial focus on a problem, then the following through of the process of collecting information, analysing information and forming conclusions. Thus, existing materials such as films, readers and resource books may be used for the collecting information stage. A graphic organizer for the analysis of information, if not provided in the teaching material, is found in references such as Bellenca (1990, 1992) and Black and Black (1990). From the charting for the analysis, the conclusion may be reached by interpreting the information on the selected chart. And, wherever choice is given in a task, students are provided with opportunities to use their creative talents. In addition, choice empowers students to pursue the challenges offered, according to their own ability.

As noted, following the study, teaching experiences by the researcher on a teaching assignment further supports the wide range of applicability of the Holland et al. (1986) framework of Induction. Specifically, the framework has been used throughout the past year in teaching thematic units from kingergarten to grade 6. A most recent example of a

problem solving situation using the framework involved grade 2 students who were questioning a playground rule made by the Principal. The rule stated that primary students were not allowed to play on a play structure that had been allocated to junior grade students. After the rule was reiterated by the Principal over the public address system, the students reacted immediately saying that there was a problem because the older students did not even play on the structure they called monkey bars. As the students were in Language Arts class at the time, the opportunity was appropriate to engage in a relevant problem solving task. All the required objectives for communication skills in the language arts curriculum; listening, speaking, reading and writing could be incorporated. Thus, after a short class discussion, the students decided that their problem centered around how to change the rule. In order to collect the appropriate information they realized they had to observe activity around the play structure. As they made their observations, some of the students made charts to analyse their information. Each day their observations were discussed and recorded on a class analysis chart. After fifteen recesses, the students' initial reactions were confirmed. Only on three occasions had older students played on the monkey bars.

In addition, the teacher questioned the safety of the structure for younger students. Through deliberations, the class realized they had to contact an expert in playground structures for the answer. They decided that a person in the local Recreation and Parks Department might be able to help and, as a result, one student was selected to make the phone call and ask the questions the class had designed. The call led to a visit to the school by the Coordinator of Parks and Recreation who confirmed the safety of the play structure after some minor repairs were made. Thus the students decided that the monkey bars should be open to students at all grade levels.

What followed was a lesson on report writing. In order to involve the whole class in the writing of the report, the students were asked to write on one of the following headings: background information, information collected at recesses, information collected from the Coordinator of Parks and Recreation and recommendations. Also, they were given a choice as to whether or not they wanted to work in groups. Once the headings or sections were written, each student or student representative from a group shared their work with the class. And, as the students read, the information was entered by the teacher into the computer. Each student was then given a copy of the computer handout. From the computer handout, a group reading lesson followed which enabled the students to collaborate and make appropriate changes. The final report was written and then distributed to the Principal with copies sent to the Vice-Principal, Coordinator of Parks and Recreation, and each student in the class (see Appendix F for a copy of the report).

Reactions from the students' report have been positive. First, the students were excited as their recommendations were accepted by the Principal. Second, the school administration, based on the teaching philosophy of Clark (1986), views student involvement in school decision making as empowering students to learn. Third, the participation of community resource people, a continuing goal for educators and recently cited in The Common Curriculum (1993), has been recognized and supported by parents. Fourth and most important, the work related to the play structure along with other study units, have demonstrated to school staff the ease of implementing a problem solving approach to teaching. As a result, curriculum planning following a problem solving approach, has been initiated for the upcoming school year. Teachers have chosen to work on one of three teams, each team to design a thematic unit for either fall, winter or the spring term. In addition, selected staff have identified and proposed the problem solving skills to be taught in each of the units. In summary, the practical application by the

researcher and the recognition of others to use the Holland et al. framework of Induction (1986) provide further support for the overall implementation of the framework to meet the recommendations in the The Common Curriculum (1993).

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APPENDIX A
REPORT OF THINKING SKILLS CONSORTIUM OF ONTARIO

**TOWARDS THE
THINKING CURRICULUM**

SUBMITTED BY:

**THE THINKING SKILLS
CONSORTIUM OF ONTARIO**

MARCH 1990

TOWARD THE THINKING CURRICULUM

MISSION STATEMENT:

The purpose of the Thinking Skills Consortium of Ontario is to recognize and promote thinking skills as a prerequisite for our students as they enter the Twenty-First Century. It is our contention that the presence of a defined thinking skills component in the curricula is necessary if we are to develop learners as "self-motivated, self-directed problem solvers who are aware of both the processes and uses of learning and who derive a sense of self-worth and confidence from a variety of accomplishments." (Issues And Directions, p.2)

BACKGROUND:

The Thinking Skills Consortium consists of representatives from many boards across Ontario who initially came together to share information and seek support as they developed thinking skills programs within their boards. These board representatives expressed a need for a consistency of approach and a coherent framework which could be used by all boards.

The Consortium members recognize the value of combining energies and expertise to scrutinize existing thinking skills models, Ministry guidelines and documents, and trends and initiatives which have recently been identified by the Ministry. Following several meetings, it was agreed that it was imperative to present to the Ministry a framework for the teaching of thinking skills which was:

- 1. Pervasive. A thinking skills framework from K-OAC should be established within which content objectives could be met. Elements from the thinking skills framework should be included in each guideline along with teaching and evaluation strategies.*
- 2. Consistent. Each guideline should indicate clear expectations regarding student acquisition and use of thinking skills within the curriculum and there should be consistency among guidelines in order to ensure transfer of skills.*
- 3. Sequential. Key skills and attitudes required by students should be identified and a program developed which would foster these skills and attitudes at each division of the school experience and in a context that will prepare students for the workplace and/or further education.*

In the past, it was assumed that children would naturally acquire thinking skills as they progressed through the school system and that the nature of the curriculum itself would foster a critical, analytical approach. Research has not borne out this assumption (Ross, Mainse 1985). Students do not improve their ability to solve problems or to think clearly without direct instruction and positive reinforcement. Transfer of skills occurs only when students are expected to use acquired skills on a regular basis in a variety of contexts (Vigotsky 1979). In order for this to happen, curriculum expectations which include thinking skills as an integral part of the curriculum must be developed.

Although recent Ministry Guidelines have attempted to incorporate some thinking skills into the program, no attempt has been made to sequence these skills or to ensure that students are introduced to a wide variety of thinking 'tools' which they can use as they are required.

As the Ministry of Education considers major changes in the structure of education in Ontario, it is our belief that changes in the delivery of education must also be considered.

Consider the following trends:

- An open economy in which Canada faces world-wide competition will require flexible, creative thinkers.*
- A rapidly changing society in which knowledge intensity leads to an accelerated pace of change will require workers with ability to; identify problems, access pertinent data, make decisions and implement action plans.*
- Changing family structures, immigration patterns and economic trends require citizens capable of using many diverse skills in order to secure personal and job satisfaction.*

Over the past decade, a variety of reports, circulars, and research studies have indicated that:

- the major purpose of a school is to help each student develop his/her potential as an individual and as a contributing, responsible member of society who will think clearly, feel deeply, and act wisely. (OSIS p. 2)*
- one of the main responsibilities of teachers is to help children become effective problem-solvers and sensitive decision-makers and life-long learners (Formative Years).*

PROPOSAL:

The Thinking Skills Consortium proposes a process oriented, cross-curricular approach to curriculum delivery which would establish a framework of thinking skills. This framework would delineate the thinking processes which should be taught from kindergarten to OAC and content objectives would be established within this framework. With this approach, students would acquire the knowledge deemed essential for students in our society as well as the thinking skills which would enable them to manipulate such knowledge in meaningful and productive ways.

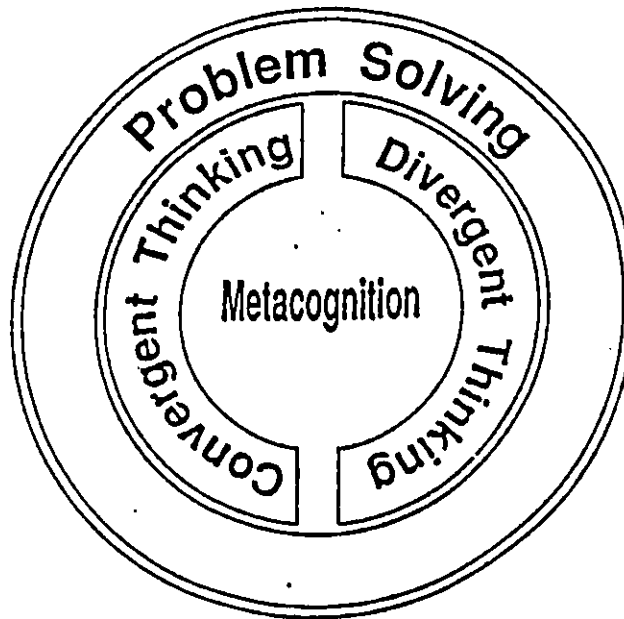
The Consortium is prepared to develop a document similar to "Partners In Action" which would present the philosophy, framework, teaching strategies and evaluation techniques appropriate for all divisions and all subject areas.

Once this document has been developed, Ministry guidelines could provide detail on the thinking skills which should be taught directly as new material and which "old" skills should be reinforced and expanded.

As well as becoming pervasive (each guideline would contain thinking skills) and consistent (each division would focus on similar skills) sequential development would also be achieved as each division emphasized basic thinking "tools" at an increasingly sophisticated level.

BASIC ELEMENTS OF THINKING

The Thinking Skills Consortium sub-committee brainstormed the following visual summary of basic types of thinking.



1. Metacognition

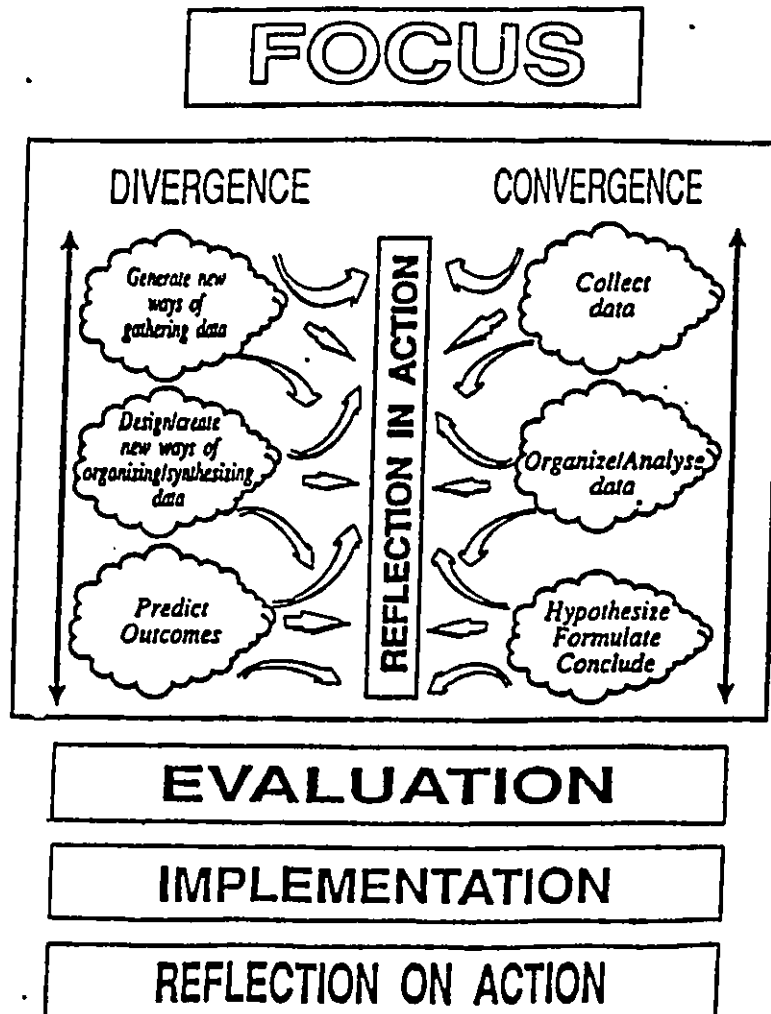
Metacognition is the focal point of all cognitive processing. It is critical that students be able to analyze their own thinking processes in order to focus effectively on the situations in the world around them.

2. Convergent/Divergent

Current literature identifies two types of thinking, divergent and convergent. Both types must be integrated into the teaching of thinking in order to achieve balance. Divergent or creative thinking skills emphasize the consideration of many ideas before proceeding to the convergent or critical thinking stage where choices are made. Examination of current Ministry documents indicates that in those guidelines where thinking skills are addressed, convergent thinking predominates. This supports perceptions that our students graduate with step-by-step linear knowledge on how to operate in specific situations but lack the creative dimension to enable them to operate effectively where a situation is loosely-defined or multi-faceted.

As our world becomes more complex, students achieve personal and professional success based on how well they solve problems. The term 'problem-solving' is used to define those complex, ill-defined situations which are increasingly associated with our modern world.

A problem-solving approach such as the following, drafted by members of the Consortium, would allow each board to develop an approach to the teaching of thinking which was appropriate for them.



The arrows demonstrate that the process is dynamic, constantly changing as new ideas are formed or discounted. Note that the process continues to repeat itself as data is evaluated against existing knowledge. While this has been designed as a guide for developing cognitive skills through the direct teaching of thinking it can also be used in affective or psychomotor skills development. Therefore it can be used in all dimensions of teaching.

SUMMARY:

All Ministry documents identify skills whether they be cognitive, affective or psychomotor which, based on a preliminary study by the Thinking Skills Consortium, fit into this approach. However, presently there is no consistency in terminology and a lack of emphasis on teaching divergent skills within Ministry documents. It is the intent of the Consortium to elaborate on this approach, indicating where skills identified in documents and current texts fit into the structure. In addition, strategies for teaching the skills would be given along with teaching lessons. The end product would be a book, Towards A Thinking Curriculum.

APPENDIX B
PARENT PERMISSION LETTER



FACULTÉ D'ÉDUCATION
FACULTY OF EDUCATION

Donna E. Ross
592-2041

Dear Parents:

I am conducting a doctoral research project, supervised by Dr. Jean Paul Dionne from the University of Ottawa, based on the teaching methods used at the Junior Level at Fitzroy for the last two years. The Research Committee of the Carleton Board of Education and my research committee of the Faculty of Education have approved my research plan. The Carleton Board of Education has granted me permission to request you and your child's cooperation in this study.

The purpose of the research is to test a method of instruction which best prepares students to solve the problems they will encounter in future years. Depending on your child's grade level, you will recall the work done with Land (Forests) and Water. This year the overall theme is Air (Atmosphere and Beyond).

All students in grades 4, 5 and 6 are being invited to participate in the study. Participation is entirely voluntarily and students may withdraw from the study at any time. Participation will be during January, February, March and June and is as follows.

1. Students will be interviewed individually on four occasions, in January, February, March and June. Interviews will be audio-taped and last approximately ten minutes. They are checks on understanding of lessons taught during the two four-week teaching units except for the first interview, which is to determine the present knowledge of the students related to the study.
2. Interpretation of student logs or journals will be made. It should be noted that the writing in the journals is part of the regular lesson planning.
3. Also, I will be making four observations in each classroom.

All information will be kept strictly confidential. This information will not appear in any school records and will be used solely for research purposes.

If you have any questions, please call me at the number given at the top of the letter. Also you may contact my supervisor, Dr. Dionne at 564-7722. Please complete the attached sheet and return it to the school as soon as possible.

Yours truly,

Donna E. Ross



RESEARCH BY DONNA ROSS
JUNIOR LEVEL - FITZROY CENTENNIAL SCHOOL
PARTICIPATION PERMISSION FORM

1. I hereby _____ give permission
_____ do not give permission

for my child _____ to participate in the study.

signature of parent of guardian

date

2. I would like to participate in the study.

signature of student

date

APPENDIX C
ATMOSPHERE AND BEYOND
CURRICULUM

ATMOSPHERE AND BEYOND

**Fitzroy Centennial Public School
Final Draft
June 1992**

ATMOSPHERE AND BEYOND

INTRODUCTION

THE TWO AIMS OF THE UNIT ARE:

- to realize that air is essential for all life forms on planet earth.
- to develop inductive reasoning skills in order for students to make informed decisions on the preservation of clean air.

The Carleton Board of Education, Process Scope and Sequence Manual has been used as a reference to identify the skills of inductive reasoning. Throughout the unit, the inductive skill being developed either collecting information, analysing information or forming conclusions is noted in parenthesis.

The unit has been written in three sections, one section to be taught each school term - fall, winter and spring. The sections are Properties of the Atmosphere, People's Relationship with the Atmosphere and What Affects Air Quality. The Content Summary Sheet on the next page describes the topics covered in each section. It should be noted that for a Ph.D research study by Donna Ross one of the writers, Segment One of Properties of the Atmosphere follows a content oriented approach rather than the inductive problem solving approach. Lessons are written according to an instructional planning model developed by the Mousseau Superintendency of the Carleton Board of Education. The model allows for the differentiation of curriculum in order to meet individual needs. The first page in each section titled, Differentiation of Curriculum provides an overview of work being taught and strategies used. Where known, the source of resource materials is also identified but many of the techniques presented originate from the actual teaching experiences of the teachers writing the curriculum.

ATMOSPHERE AND BEYOND
CONTENT SUMMARY SHEET

GENERAL PARAMETERS/INSTRUCTIONAL EFFECTIVENESS MODEL

SECTION ONE - PROPERTIES OF THE ATMOSPHERE

Properties of air
Layers of the Atmosphere
Composition of the Sun
Planets Relationship to the Sun
Travel of Light
Seasons

SECTION TWO - PEOPLE'S RELATIONSHIP WITH THE ATMOSPHERE

Transportation - history of air travel
Communication - importance sound waves, function of human ear, contributors, types and purpose of satellites
Recreation - kites, rocketry, ballooning, models

SECTION THREE - WHAT AFFECTS AIR QUALITY

Ozone Layer
Greenhouse Gases
Global Warming

PROPERTIES OF THE ATMOSPHERE

**Developed by:
Harold Fraser
Steve Lapp
Donna Ross
Barrie Stewart
May 1991**

**Revised by:
Harold Fraser
Sheila Reid
Donna Ross
Barrie Stewart
February 1992**

ATMOSPHERE AND BEYOND
DIFFERENTIATION OF CURRICULUM
Meeting Individual Needs

TITLE: PROPERTIES OF THE ATMOSPHERE

SUBJECT AREA: ENVIRONMENTAL STUDIES

DIVISION: JUNIOR

AIMS: To realize that the atmosphere is essential for all life forms on earth
 To develop inductive reasoning skills in order to make informed decisions on the wise conservation and use of air

RATIONALE : Air quality is critical to the well being of students in future years

OBJECTIVES:

The student shall:

- know the layers of the atmosphere; troposphere, stratosphere, ionosphere, exosphere
- know that air has weight, air occupies space, air has pressure, heat expands air and air rises when heated
- know the composition of the sun
- know the names, sizes of planets and their position in relation to the sun
- explain the travel of light
- explain the reasons for seasons
- compare aspects of the atmosphere: planets, travel of light, seasons, life in different places
- decide on a place to live based on: atmospheric conditions, interests, health and money

CONTEXT

The study is divided into two segments written according to the Mousseau Superintendency Planning Model. Differentiation occurs with brighter students being offered further challenge in the INDEPENDENT WORK portion of the Mousseau Model. Reinforcement for students needing more assistance is provided through the GUIDED PRACTICE portion.

TEACHING LEARNING STRATEGIES

- experiments, demonstrations, films, videos, interview with expert, dramatizations, independent study, readings, charting and group work

EVALUATION

- teacher, group and self-evaluation

IMPLEMENTATION

- **approximately** ten forty-five minute lessons for each of the two segments.

RESOURCES

- Environment Canada - Current Weather Calendar
- CBE Process: Scope and Sequence Manual - Critical Thinking, Inductive

Reasoning and Decision Making

- Instructional Effectiveness Model - Mousseau Superintendency
- Films - Ottawa Carleton Media Centre:
- FLIGHT - Carleton Board of Education, developed by Bill Baird and John Fallis
- The Young Scientist Book of Stars and Planets - Hayes Usborne
- Exploring the Night Sky - The Equinox Astronomy Guide for Beginners -

Camden House Publishing

- Exploring the Sky by Day - The Equinox Guide to Weather and the Atmosphere -

Camden House Publishing

- Keepers of the Earth by Michael J. Caduto and Joseph Bruchac, Fifth House Publishers, Saskatoon, Saskatchewan.

SECTION ONE - PROPERTIES OF THE ATMOSPHERE CONTENT ORIENTED ENVIRONMENT

SEGMENT ONE - PROPERTIES OF AIR (APPROXIMATELY TEN FORTY-FIVE MINUTE LESSONS)

SET

Before beginning the unit, record the weather for one week. Note effects such as change in clothing, activities and feelings. It is important to include world wide effects related to weather such as hurricanes which are prevalent during the fall.

Display pictures related to weather under the headings, WHAT IS HAPPENING? WHY?

Show film SKY #10-1383

OBJECTIVES

The student shall:

- know the layers of the atmosphere; troposphere, stratosphere, ionosphere, exosphere

The student shall know that in the troposphere:

- air has weight, air occupies space, air has pressure, heat expands air and air rises when heated.

METHOD - ONE FORTY-FIVE MINUTE LESSON

The student shall:

- listen to teacher refer to film, weather observations or pictures in bulletin board display to tell that these events are occurring in the layer surrounding our earth called the troposphere
- introduce terms for other layers, stratosphere, ionosphere and exosphere noting that the students will learn more about them later.

- write down answers to questions in bulletin board display, WHAT IS HAPPENING? WHY?

- share answers with classmates

FIVE FORTY-FIVE MINUTE LESSONS

The student shall:

- observe and participate, where feasible, in the following experiments:

Experiment 1 - Air Has Weight

Materials:

metre stick, two balloons

Procedure:

Using a metre stick, balance two balloons not filled with air at each end.

Blow up one balloon.

Observe.

Experiment 2 - Air Occupies Space

Materials:

Container, glass to fit container, water, wood chip

Procedure:

Fill the container with water.

Place a floating wood chip in the water.

Invert a glass over the wood chip and push the glass into the water.

Observe.

Tilt the glass so the water goes into it.

Experiment 3 - Air Has Pressure

Materials:

Clean tin can with a screw lid such as maple syrup can, water, heating device as candle

Procedure:

Fill one quarter full of water.

Heat the can without the lid.

Put on the lid.

Let cool.

Observe.

Experiment 4 - Heat Expands Air

Materials:

erlenmyer flask, balloon, heating device

Procedure:

Stretch base of balloon and place over mouth of flask.

Heat flask.

Observe.

Experiment 5 - Air Rises When Heated

Materials:

Convection box, candle

Procedure:

Light candle.

Close glass of convection box.

Take paper towel - blow out until smoke - see path air takes

Hold over chimney that does not have candle.

Note: Smoke will be sucked down chimney and go across and up other chimney.

Air above candle is rising and cooler air is drawn in from side where towel has been placed.

Smoke shows circular path of air - shows convection - causes wind

CHECK FOR UNDERSTANDING

The student shall:

-in groups or individually, find other experiments in available Science books that also explain that air has weight, air occupies space, heat expands air and air rises when heated. Conduct experiment at home or at school, illustrate and present to class.

GUIDED PRACTICE

The student shall:

- after each experiment write up the experiment according to the following format:

Hypothesis:

Purpose:

Apparatus:

Method:

Observations:

Conclusions:

Application in Real World.

Write up with a partner if more help is needed.

2.View the films:

AIR AND WHAT IT DOES #10-1092

THE OCEAN OF AIR#20-1054

INDEPENDENT WORK

The student shall:

- design questions that could be asked to a weather reporter to gain more information on weather. If appropriate, invite a weather reporter to school to answer the questions.

EVALUATION

- teacher - test - students answer questions based on experiments such as, "What happened when the lid was put on the heated can that was half filled with water?"

- teacher - accuracy and neatness of written experiments

SECTION ONE - PROPERTIES OF THE ATMOSPHERE PROBLEM SOLVING ORIENTED ENVIRONMENT

SEGMENT TWO - THE SOLAR SYSTEM (APPROXIMATELY TEN FORTY-FIVE MINUTE LESSONS)

SET - (TWO FORTY-FIVE MINUTE LESSONS)

The student shall:

- as a member of a group (class divided into three groups) read or listen to either a Greek, Roman or Native legend about the origin of the universe (appendix 1- examples of Greek and Native legends - other Native legends found in book Keepers of the Earth)
- answer questions related to content (appendix 2)
- listen to selected group member, using question sheet, share information with other groups
- respond orally to teacher question, "HOW DO WE COMPARE LEGENDS ABOUT THE ORIGIN OF THE UNIVERSE?"
- listen to teacher tell the main purpose of the unit, to learn how to compare - respond to teacher question, "Why is it important to know how to compare?"

OBJECTIVES

The student shall:

- know the composition of the sun
- know the names, size of planets and their position in relation to the sun
- explain the travel of light
- explain the reason for seasons
- compare aspects of the atmosphere: planets, travel of light, seasons, life in different places
- decide on a place to live based on: atmospheric conditions, interests, health, money

METHOD - CHECK FOR UNDERSTANDING - (EIGHT FORTY- FIVE MINUTE LESSONS)

NOTE: At the beginning of each lesson teacher should tell the students to think of what they can compare based on what they have learned in the lesson.

Then at the end of the lesson talk about what comparisons can be made. Keep a running record of these comparisons on chart paper posted in classroom.

Lessons 1 to 7 (collecting information)

Lesson 1 - COMPOSITION OF SUN

The student shall:

- view film about the SUN
- write a summary note based on information about the film

Lesson 2 - NAMES, SIZE AND POSITION OF PLANETS

The student shall:

- respond to the following tasks in order to make an illustration of the planets and their relation to the sun.

- move into teacher selected groups of four
- listen to teacher explain the responsibilities of each member which has previously been selected by the teacher.
 - reader - reads the assigned task
 - drawer - illustrates what is to be done
 - leader - tells drawer where to place information
 - checker - makes sure information is correct before it is recorded
- read and then respond to following task sheet which has been distributed to each group
- before starting group task, leader tells group how they are going to proceed.

Think of a baseball diamond. Sketch it lightly on the blank sheet of paper given to you so that you can erase it later. At home plate make a ball the actual size of a baseball. That is the sun.

Then between home plate and the pitcher's mound make first Mercury, then Venus, then Earth and last Mars. Make each of them the size of the lead in a pencil. If you want to be exact Mercury is $\frac{1}{8}$ of the way, Venus $\frac{1}{5}$, Earth $\frac{1}{3}$ and Mars $\frac{1}{2}$.

At second base is Jupiter, the size of a big pea.

In shallow centre field is Saturn, just a bit smaller than Jupiter.

Uranus, the size of this O is at the fence in deep centre field.

Neptune, the size of this O is just outside the park with Pluto just beyond looking just like a . .

- erase lightly sketched baseball diamond and make illustration more attractive
- label a stencil of the planets and paste in notebook (appendix 3)

Lesson 3

The student shall:

- make up a RAP to help remember the names of the planets - perform for the class.

Lesson 4 - TRAVEL OF LIGHT

The student shall:

- complete the following experiment:

Experiment # 6 - Travel of Light/ Light Travels in a Straight Line

Materials:

filmstrip machine, three pieces of cardboard, 8 1/2" by 11" with hole the size of a pencil, punched in various places, three pieces of cardboard with same sized hole punched in same place in each one

Procedure:

Line up cardboards, each set in plasticine to stand erect, with holes punched in various places, shine projector through them. Observe.

Do the same with cardboards with holes punched in same spot.

Introduce term **rays** saying that a beam of light is made up of thousands of rays.

Lesson 5 - EXPLANATION OF SEASONS

The student shall:

- complete the following experiment:

Experiment #7 - Direct Rays and Slanted Rays

Materials:

two thermometers, two bookends.

Procedure:

Tape thermometers perpendicular to each other on bookends.

Shine light on both simultaneously.

Record temperatures.

Lesson 6 - EXPLANATION OF SEASONS

The student shall:

- sit around a projector which has been placed in centre of classroom (projector is placed in centre of circle of represent sun).
- observe classmate walk around outside of circle of students carrying a world globe, always pointing to an X that teacher has put on chalkboard. (X signifies the north star to which the earth's axis always points)
- observe second student walk around circle with projector light turned on
- describe which parts of the earth receive light at various positions on the circle's path
- translate observations and knowledge from experiment #7 into a description of seasons, fall, winter, spring and summer.
- locate a spot on the globe, tell the season and then tell what people could be doing at that point because of the weather.
- complete question sheet and paste in notebook (appendix 4).

Lesson 7

The student shall:

- repeat lesson 6
- draw a diagram of sun and earth's orbit in notebook.

Lesson 8 (analysing information)

Lesson 8 - COMPARING LIFE AT THE SAME TIME OF TWO PLACES ON EARTH

The student shall:

- listen to teacher explain purpose of lesson - to compare life at the same time at two different places on the earth
- as a class, make a comparison chart to compare activities/life of people at two different places on the earth. Do as follows:

- choose two places.
- decide on at least five categories that could be compared such as climate, homes, recreation
- set up accordingly.

Category	Place	Place	Same or Different or Unique

- take one category at a time and write a note comparing life in the two places making sure to note whether same or different or unique

- give examples of other comparisons that could be made
- tell why it is important to know how to compare (teacher lead discussion to extend into comparison in real life situations)
- work in groups to design a comparison chart comparing life in their area to another place on earth

Guided Practice (forming conclusions)

GUIDED PRACTICE

The student shall:

- individually, using group comparison chart, decide which place is better to live.
- write a comparison note to explain the decision.

INDEPENDENT WORK

The student shall:

- research in depth one of planets or choose a phenomenon and make up own explanation for it - make sure explanation is a synthesis of correct information to date.

EVALUATION

- teacher - accuracy of summary note, written experiments and comparison note
- student - RAP - rank from 1 to 10 for each of: originality, knowledge of planets and presentation
- group - evaluate process of other group comparison charts, rank from 1 to 10 each of: design, selection of headings, content of cells

**PEOPLE'S RELATIONSHIP
WITH THE ATMOSPHERE**

**Developed by:
Harold Fraser
Sheila Reid
Donna Ross
Barrie Stewart**

March 1992

ATMOSPHERE AND BEYOND
DIFFERENTIATION OF CURRICULUM
Meeting Individual Needs

TITLE: PEOPLE'S RELATIONSHIP WITH THE ATMOSPHERE

SUBJECT AREA: ENVIRONMENTAL STUDIES

DIVISION: JUNIOR

AIMS: To realize that the atmosphere is essential for all life forms on earth
To develop inductive reasoning skills in order to make informed decisions on the wise conservation and use of air

RATIONALE : Air quality is critical to the well being of students in future years

OBJECTIVES:

The student shall:

- know the principles of flight
- make a model to show principles of flight
- participate in experiments that show principles of flight
- research airborne vehicles, either non mechanical, propellor, jet or rocket type
- show relationship of three types of vehicles to each other
- choose the most valuable type for present use
- understand sound travels through air
- know the significance of sound waves, frequency, pitch
- know the function of the human ear
- know the contribution of Morse, Marconi, Bell
- organize events in sound communication through air on a time line
- decide how these events impact on life today
- follow a blueprint to make a kite, air balloon or rocket.

CONTEXT

The study is divided into three segments written according to the Mousseau Superintendency Planning Model. Differentiation occurs with brighter students being offered further challenge in the **INDEPENDENT WORK** portion of the Mousseau Model. Reinforcement for students needing more assistance is provided through the **GUIDED PRACTICE** portion.

TEACHING LEARNING STRATEGIES

- experiments, field trip, films, videos, demonstrations, independent study, readings, charting and group work

EVALUATION

- teacher, group and self-evaluation

IMPLEMENTATION

- approximately SEVEN weeks - thirty-two forty-five minute lessons - recommended that SEGMENT THREE eight forty-five minute lessons be transferred to spring term as it involves outdoor activity and last unit only eight forty- five minute lessons

RESOURCES

- CBE Process: Scope and Sequence Manual - Critical Thinking, Inductive Reasoning and Decision Making
- Instructional Effectiveness Model - Mousseau Superintendency
- Films - Ottawa Carleton Media Centre:
- FLIGHT - Carleton Board of Education, developed by Bill Baird and John Fallis
- REACT - method of research - available from Carleton Board Librarians
- FWTAO Curriculum Insert, Let's Fly a Kite, 1989/90, Vol. 8, No 4.
- Science is Happening Here, Flights and Kites, Vol. 3, No. 3.

SECTION TWO - PEOPLE'S RELATIONSHIP WITH THE ATMOSPHERE

SEGMENT ONE - TRANSPORTATION- THE HISTORY OF AIR TRAVEL - (APPROXIMATELY FOURTEEN FORTY-FIVE MINUTE LESSONS)

SET -

The student shall:

- view film Birds Can Fly, Why Can't I (BPN 337001)
- respond to teacher question, What is critical about being able to fly?

OBJECTIVES

The student shall:

- know the principles of flight
- make a model to show the principles of flight
- research airborne vehicles, either non mechanical, propellor, jet or rocket type
- show relationship of three types of vehicles to each other
- choose the most valuable type for present use

METHOD AND CHECK FOR UNDERSTANDING FOUR FORTY-FIVE MINUTE LESSONS

NOTE: At the beginning of the unit and reinforced at the beginning of each lesson teacher should tell students, "We are finding ways to organize our thinking because we are going to be learning so much information about flight. During the research part of our work the REACT method helps us to organize. When we have the facts organized then we will learn how these facts relate to each other by using another way to organize our thinking."

The student shall:

- listen to teacher directed lesson explaining the principles of flight (information found in appendix 5)
- make a flying machine with given materials, 1 sheet tissue paper, 1 paper plate
- fly machine to determine which one stays in air longest and which one goes the farthest
- relate design of winner to principles of flight (collecting information)

EXPERIMENTS - PRINCIPLES OF FLIGHT (collecting information)

The student shall:

- try at least six of the following experiments written on task cards
- record observations and tell what principle of flight is observed, thrust, drag or lift

Experiment 1 - Gravity

Materials:

paper cups, playing cards

Procedure :

Stack the cups open end down with a card in between each cup.
Start at the top and quickly pull out the card between each cup.
Observe.

Experiment 2 - Lift

Materials:

pencil, paper cup, sheet of paper

Procedure:

Put the paper on the desk.

Use the other objects to pick up the paper without touching the paper.

Observe.

Experiment 3 - Drag

Materials:

2 identical sheets of paper

Procedure:

Crumble one sheet of paper into a ball.

Stand and hold the paper ball in one hand and the sheet of paper in the other hand.

Hold hands at the same height and drop the papers at the same time.

Observe.

Experiment 4 - Lift

Materials:

two balloons inflated to the same size, two pieces of string 30 cm long

Procedure:

Use the string to hang the balloons so there is 3 cm between them.

Blow gently between the balloons.

Observe.

Experiment 5 - Thrust

Materials:

180 cm of string, tape, balloons, one straw

Procedure:

Run the string through the straw and tie the two ends of the string to two chairs.

Pull the chairs apart to make the string taut (tight).

Blow up one balloon half way, and hold the neck closed.

Tape the balloon to the straw.

Pull the balloon to one chair and let the balloon go.

Observe.

Repeat the experiment but this time blow up the balloon all the way.

Observe.

Repeat but go in the opposite direction.

Observe.

Experiment 6 - Lift

Materials:

8 cm x 13 cm card, funnel

Procedure:

Hold the funnel with the large end down over the card.

Suck air through the funnel.

Observe.

Blow air through the funnel.

Observe.

Experiment 7 - Lift

Materials:

5 cm x 25 cm paper strip

Procedure:

Hold the strip with two hands just under lower lip.

Blow.

Observe.

Experiment 8 - Drag/Gravity

Materials:

different objects such as pencil, cap, sock, book or shoe

Procedure:

Hold a different object in each hand.

Hold the objects at the same height and drop them at the same time.

Observe.

Experiment 9 - Lift

Materials:

one stamp, one quarter

Procedure:

Lay the stamp on desk.

Hold the quarter 3 cm over the stamp and blow down on the coin.

Observe.

Experiment 10 - Drag

Materials:

large sheet of bristol board

Procedure:

With a partner run a race.

One person should hold the bristol board in front of them as they run.

Record the results.

Experiment 11 - Gravity

Materials:

4 different coins, metre stick

Procedure:

Place the coins on the metre stick.

Carefully hold the stick overhead.

Tilt so the coins fall.

Observe.

FIVE FORTY-FIVE MINUTE LESSONS

- view film, Those Magnificent People in their Flying Machines (BPN 337002) (collecting information)

- visit an aviation museum (collecting information)

- choose topic for research either: Non Mechanical Machines as gliders, air balloons, dirigibles, blimps, Propelled Airplanes, Jets or Rockets.

- use REACT method to conduct research (appendix 6) except write information under the following headings:

How it gets going

How the atmosphere helps or hinders

How does its structure direct the craft

How does it land

· Other - this section is important **in case**: in information already known component of REACT process some information does not fit in above sections (analysing information)

SIX FORTY-FIVE MINUTE LESSONS

- present research to class **and** on same day listen to other projects about same topic (forming conclusions)

Note: As student is presenting research, teacher writes down key facts under headings used in project. At this point teacher states that we have many facts organized under headings. Now we are going to learn a way of seeing how the facts are connected to each other or how they relate to one another.

- as a class, pick two types of vehicles **and** under teacher direction, use a class relationships diagram to determine the relationship of one to the other (appendix 7) (analysing information)

- work with a partner who chose another type of vehicle to research and fill in a class relationships diagram (analysing information)

- work with two other students who chose different topics and complete a class relationships diagram using the **three** types of vehicles (analysing information)
- individually decide which type of vehicle is most beneficial in the world today (forming conclusions)

- write a report, present a TV commercial or create a poster to convince others (forming conclusions)

GUIDED PRACTICE

The student shall:

research - check with teacher as each step is completed before moving to next stage according to REACT method

class relationships diagram - ask others in group or other groups for clarification

convincing report, TV program or poster - make sure class relationships diagram that was made is continually referenced

INDEPENDENT WORK -

The student shall:

- visit an expert to have pre-designed questions answered about air travel

EVALUATION

- teacher - research - organization and facts presented
- peer - accuracy of relationships diagram using three vehicles
- student - complete checklist of facts presented in convincing poster, report to demonstrate understanding of relationships diagram
- student - number of other times I can compare, I can use REACT, I can use a class relationships diagram

SECTION TWO - PEOPLE'S RELATIONSHIP WITH THE ATMOSPHERE

SEGMENT TWO - SOUND COMMUNICATION (APPROXIMATELY TEN FORTY-FIVE MINUTE LESSONS)

SET

The student shall:

- listen to story about first communication through air - homing pigeon
- talk about why communication of this type was considered

OBJECTIVES

The student shall:

- understand sound travels through air
- know the significance of sound waves, frequency, pitch
- know the function of the human ear
- know the contribution of Morse, Marconi, Bell
- organize events in sound communication through air on a time line
- decide how these events impact on life today

METHOD - CHECK FOR UNDERSTANDING - Lessons 1 to 6 (collecting information)

Lesson 1

The student shall:

- participate in following experiment:

Experiment 1 - Sound Travels Through Air

Materials:

sealed glass jar, electric bell inside, vacuum pump (available from secondary school science departments)

Procedure:

- Ring bell inside jar.
- Listen for sound.
- Start vacuum pump to withdraw air from jar.
- Ring bell.
- Listen for sound.
- Record results.

Lesson 2

Frequency and pitch

The student shall:

- listen to music played by various musical instruments
- determine why sound is different
- drop penny in pond - observe formation of rings
- note the similarity to sound wave travel
- place ruler over end of desk - tap
- change length of hanging portion - tap again
- note the changes in pitch.

Lesson 3**Function of the Human Ear**

The student shall:

- obtain books on topic from library
- in groups read the information
- be ready to explain the function of the ear to others
- make a diagram in notebook

Lesson 4, 5 and 6

The student shall:

- in groups obtain information on either Morse, Marconi or Bell.
- using jig saw approach share information with others in class.

Students at this point should be made aware that they have gained a great deal of information about the evolution of sound communication and that it is important to organize that information. The teacher then suggests a time line.

The student shall:

- begin filling in time line of important events in sound communication. (analysing information)

Lesson 8**Effect from analysis of time line (forming conclusions)**

The student shall:

- debate or discuss the statements, Things have happened too fast. The world is or is not a better place today than the world of Morse, Marconi or Bell.

GUIDED PRACTICE

The student shall:

- throughout group work, listen to others read information and be ready to ask others in for help

INDEPENDENT WORK

The student shall:

- visit an airport control tower, talk to a satellite dish distributor, expert from Telsat to find how communication is carried out.
- Report and record important events on class time line.

EVALUATION

- teacher - notebook - accuracy and neatness of recorded information
- group - ability to support point of view with factual information

SECTION TWO - PEOPLE'S RELATIONSHIP WITH THE ATMOSPHERE

SEGMENT THREE - RECREATION (APPROXIMATELY EIGHT FORTY-FIVE MINUTE LESSONS)

SET

The student shall:

- observe pictures or models of aircraft
- talk about what skills are needed to make one

At this point the teacher should stress the importance of information being sequenced or in order and to make such air vehicles ordering or following instructions is important.

OBJECTIVES

The student shall:

- follow a blueprint to make a kite, air balloon or rocket (for air balloon see appendix 8)

METHOD

The student shall:

- read all the instructions related to task (collecting information)
- decide whether understand well enough to complete
- gather materials
- follow directions for assembly (analysing information)
- participate in an air show (forming conclusions)

CHECK FOR UNDERSTANDING

The student shall:

- follow instructions to make a packaged balsa wood glider

GUIDED PRACTICE

The student shall:

- explain process of making aircraft to partner or teacher before beginning and, as each step is completed talk about next step before actually doing.

INDEPENDENT WORK

The student shall:

- teach a younger child to make an aircraft which would be too complex to make independently

EVALUATION

- student - was aircraft completed for air show
 - did it get air borne

WHAT AFFECTS AIR QUALITY

**Developed by:
Harold Fraser
Sheila Reid
Donna Ross
Barrie Stewart**

March 1992

ATMOSPHERE AND BEYOND
DIFFERENTIATION OF CURRICULUM
Meeting Individual Needs

TITLE: WHAT AFFECTS AIR QUALITY

SUBJECT AREA: ENVIRONMENTAL STUDIES

DIVISION: JUNIOR

AIMS: To realize that the atmosphere is essential for all life forms on earth
To develop inductive reasoning skills in order to make informed decisions on the wise conservation and use of air

RATIONALE : Air quality is critical to the well being of students in future years

OBJECTIVES:

The student shall:

- know and understand ozone layer
- know and understand greenhouse gases
- know and understand global warming
- identify central or main issues related to each of the above
- write letter to industrial associations to ask how they are attempting to correct current problems

CONTEXT

The study is divided into one segment written according to the Mousseau Superintendency Planning Model. Differentiation occurs with brighter students being offered further challenge in the INDEPENDENT WORK portion of the Mousseau Model. Reinforcement for students needing more assistance is provided through the GUIDED PRACTICE portion.

TEACHING LEARNING STRATEGIES

- readings, charting and group work

EVALUATION

- group

IMPLEMENTATION

- **approximately** eight forty-five minute lessons

RESOURCES

- Environment Canada - Current publications on Air
available from:
**Environment Canada
Publications Office, 1 st floor,
Place Vincent Massey
Hull Quebec, K1A 0H3**
- CBE Process: Scope and Sequence Manual - Critical Thinking,
Inductive Reasoning
- Instructional Effectiveness Model - Mousseau Superintendency

UNIT THREE- WHAT AFFECTS AIR QUALITY

SEGMENT ONE- OZONE LAYER, GREENHOUSE GASES, GLOBAL WARMING

SET

As a class make a webbing diagram with air in the middle to review knowledge about air. Then pose question, What is happening to air today? List facts on board. Identify need to find more information on the ozone layer, greenhouse gases and global warming.

OBJECTIVES

The student shall:

- know and understand ozone layer
- know and understand greenhouse gases
- know and understand global warming
- identify central or main issues related to each of the above
- write letter to industrial associations to ask how they are attempting to correct current problems

METHOD

The student shall:

- in mixed ability groups read current literature from Environment Canada either on the ozone layer, greenhouse gases or global warming (collecting information)

At this point students should be told that they are going to organize their thinking about all the information they have about the ozone layer, greenhouse gases and global warming by identifying the central or main idea

- on chart list the main points given in the article
- choose three of the main points (analysing information)
- present the three points to the rest of the class
- list on board with points given from other two groups
- as a class select three points from the list on board (analysing information)
- write a letter to an industrial association citing the three selected points and asking what is being done to correct problem
- volunteer to read letter to class with class as a group selecting and recording good ideas from each letter as read
- as a class write one letter using ideas from student letters, sign and mail (forming conclusions)

CHECK FOR UNDERSTANDING

The student shall:

- work in teacher directed group after each step in gleaming main ideas

GUIDED PRACTICE

The student shall:

- work in mixed ability groups and ask for help if needed

INDEPENDENT WORK

The student shall:

- write letter to local government noting work that has been done in class and asking their initiatives to **SAVE THE ENVIRONMENT**
- as follow up to response recommend initiatives to local government

EVALUATION

group - responses from letters written

Appendix 1

Greek Legend**Mother Earth and Her Children** (source unknown)

In the very beginning, there was no earth or sea or sky. There was only a mass of confusion in darkness, called Chaos.

After many, many years Mother Earth, named Gaea, was born out of Chaos. And after many more years, she gave birth to a son, Uranus, who was Father Heaven.

Father Heaven loved Mother Earth, and he made rain fall on her, so that flowers and trees and grass grew. The rain also fell into hollows and crevices, forming seas and rivers and lakes. Then Mother Earth created many kinds of animals to live in the forests and fields and oceans and lakes.

Mother Earth and Father Heaven had many children. First Mother Earth gave birth to three monstrous sons, each with fifty heads and one hundred hands. Then she gave birth to three more gigantic sons, just as ugly, called the Cyclopes. Each Cyclops had only one eye right in the middle of his forehead. These six sons were as strong as earthquakes and tornados put together. And they were often as destructive.

Finally Mother Earth bore the first gods, six sons and six daughters called the Titans. They, too, were gigantic, yet somewhat more like humans than her first children. They were just as strong as her first six sons, but sometimes they used their power wisely.

Father Heaven could not stand the sight of his first six ugly sons, and he was afraid of them, too. One day he threw them into a dark hole under the earth.

Mother Earth cried bitterly over this cruelty to her children. She decided to destroy Father Heaven and bring back her beloved children. She made a weapon, a sickle, and gave it to the Titans. "Kill your cruel father," she begged them, "and then go down into that dark hole and bring your brothers back to me."

Cronus, the strongest and bravest of the Titans, led the attack on his father and wounded him dreadfully. Then he released his brothers. The Titans made Cronus the ruler of heaven and earth and their sister, Rhea, his wife and queen.

But power changed Cronus, and now he imprisoned his brothers, the one-eyed Cyclopes and the hundred-handed monsters, in that dark hole under the earth.

This enraged Mother Earth, but she did not tell Cronus how she felt. She bided her time while Cronus's wife, Rhea, bore sons, for she knew that one of them was destined to overthrow Cronus.

Cronus, too, knew that one of his children was to rise up against him and take his place as king of the gods. Therefore, to keep his children from growing up and becoming powerful, he swallowed them as soon as they were born.

Rhea was deeply saddened as, one by one, Cronus devoured her first five children: Hestia, Demeter, Hera, Hades, and Poseidon. When she was expecting her sixth child,

she was determined to save it from Cronus. After her baby son, Zeus, was born, she gave him to Mother Earth, who hid the baby in a cave on the island of Crete.

Then Rhea went to Cronus and said, "Here is our sixth child, a son. Do whatever you wish with him." She handed Cronus a bundle that looked like a baby wrapped in a blanket.

Of course Cronus swallowed it, just as Rhea had expected.

But Cronus had swallowed a stone wrapped in a blanket, not the baby Zeus.

Now Rhea was happy. She hoped that Zeus was the son who would destroy his frightful father, Cronus.

Zeus grew up on Crete among shepherds and nymphs, far from his wicked father, Cronus. He drank the milk of a goat nymph, who fed him honey, too. He slept in a golden cradle that was hung from a tree and armed guards protected him. Whenever he cried, the guards banged their spears on their shields so that Cronus would not hear Zeus's loud wails and know that he still lived.

Nevertheless Cronus learned that his son was alive on Crete, and he went after him, intending to swallow him. But Zeus was too clever for Cronus. He changed himself into a serpent, and though Cronus searched high and low, he could not find Zeus.

Rhea, Zeus's mother, had told him about the terrible deeds of his father, and Zeus vowed that when he was fully grown, he would rescue his brothers and sisters.

At last that time came. Zeus returned to Rhea and disguised himself as a servant in Cronus's palace. Then he and Rhea laid their plot. "If you will concoct a poisonous potion," said Zeus to his mother, "I will mix it into Cronus's drink." His mother agreed readily, and when the poisoned drink had been prepared, Zeus served it to Cronus. Cronus drank it quickly, for he was thirsty. He became very ill and vomited up the stone he had swallowed. The pains continued as, one by one, out of Cronus's mouth sprang his five children.

Zeus's brothers and sisters hugged him and thanked him for giving them new life. "And now that you have set us free," they said to Zeus, "you must lead us in a battle against Cronus and the Titans. We, not they, must rule the universe, and never again will we be imprisoned."

The terrible war raged for ten long years, Cronus was no longer young, so Atlas led the Titans. However, two other Titans, Prometheus and Epimetheus, joined Zeus and his brothers and sisters. That made the two sides nearly equal in strength. Neither could win.

Finally wise Mother Earth told Zeus that his side would be victorious if he followed her advice. "Go down into the dark hole under the earth and release the one-eyed Cyclopes and their hundred-handed brothers, for they shall help you win."

Zeus followed Mother Earth's advice and descended bravely into the dark hole. He killed the guard and freed the prisoners. Then he gave them divine food and drink, and at last their strength returned.

The Cyclopes, in turn, gave Zeus gifts to use as weapons against Cronus and the Titans.

"To Zeus," said one of the Cyclopes, "we give our powerful weapons, the thunderbolts."

"To Zeus's brother Hades," said another, "we give this magic helmet of darkness."

"And to their brother Poseidon," said the third, "we give this sharp-pronged trident."

Zeus and Hades and Poseidon thanked the Cyclopes and discussed how best to use their gifts.

Then Hades put on his helmet of darkness, which made him invisible. He crept up behind Cronus and stole his weapons.

Poseidon struck the ground with his trident, which caused the earth to shake. Cronus became powerless.

Then Zeus threw his thunderbolts, and Cronus and Atlas and the rest of the Titans retreated.

Meanwhile the three hundred-handed brothers hurled three hundred rocks at the Titans, all at once, over and over.

The earth was almost torn apart by the dreadful battle, but before it could be destroyed, Zeus and his brothers and sisters won. They punished all the Titans except for Prometheus and Epimetheus who had helped them. They made Atlas, the Titans' leader, carry the whole sky on his shoulders forever. And they chained Cronus and the others in the dark hole under the earth.

Zeus could not rest long, though, for Mother Earth gave birth to one more enemy, the most terrible of all, a monster named Typhon. Typhon had one hundred heads and spurted a stream of fire from each eye. But Zeus hurled his thunderbolts and struck down that hideous creature. At last there was peace on earth.

Now which of the three brothers, Zeus, Poseidon, or Hades, should be the ruler of the universe? They had had enough fighting and they wanted to settle this problem without an argument.

They decided to draw lots. Hades won the underworld, and Poseidon won the sea. And Zeus became lord of heaven and ruler of all the gods of Mount Olympus. .

Native Legend - Haida

The Raven and The Ball of Light (source unknown)

Darkness had covered the earth for a long time and the Raven was fed up with it. He couldn't see a thing, not even himself in this dark world, as his black shiny plumage was indistinguishable from the ever-black night.

One day, he heard a rumor that the old fisherman who lived alone except for his pretty daughter at North Island kept a ball of bright light hidden in his big house by the sea. The Raven wanted to end the age of darkness in which he was living, so he decided to steal the light and release it in the world.

The next summer, that is, during the season when salal berries ripen, he changed himself into a dark green shiny salal leaf. The fisherman's daughter was gathering salal berries in a wild fruit patch and while eating some of the small, juicy blue fruit, she swallowed the leaf. As soon as the Raven entered her body, he changed again from a leaf to an unborn human baby, who in the fullness of time emerged in the normal way, much to the surprise and baffled annoyance of the girl and her father.

The baby grew with amazing speed and soon became a very mischievous child and at the same time a very appealing one. He soon became a great favorite of his grandfather. The old man gave him everything he wanted, until one day he began to cry for the ball of light which was kept in a bent corner box. For many days the grandfather refused this request but finally, by begging and crying, the Raven overcame his resistance and persuaded the old man to give him the light.

"Give my grandson what he is asking for; give him the ball of light," he said to his daughter.

The young mother went behind the screen at the back of the big house and brought back the wooden chest beautifully ornamented with abalone shell in which the bright ball of light was kept.

She opened the box and in it was another box, which she also opened. She found a third box, a little smaller, inside; after the third, a fourth, a fifth, a sixth, until she reached the tenth box. This last box was very carefully wrapped in a fine net made of nettle fiber, which she removed to get at the lid. She lifted the lid and a flood of light filled the big plank house as the sun itself appeared, for the first time, free, bright and round like a ball.

"Here's your light," said the young mother to her son, throwing it to him with a deft hand, "Take it!"

The child caught it in its first flight through the air with great joy. But he soon began to whimper again, and his whimpering turned to tears and sobs.

His grandfather, who could not bear to hear him cry, asked his daughter, "What is the matter with my grandson now?"

She found out that the child had still another wish. The smoke hole of the big house was closed by the roof boards and the child wanted them removed.

"Open the smoke hole for my grandson," said the grandfather.

No sooner had she opened the smoke hole to the opaque black sky than the child immediately transformed himself into his real shape, that of the supernatural Raven. With the sun in his bill - some say under one of his wings - the Raven flew out of the smoke hole in the roof of the house.

As he was flying away with his prize he encountered the Eagle who chased him and forced him to drop it. It fell and broke into many pieces, the large ones forming the Sun and the Moon, and the small ones the stars in the night sky.

Appendix 2

Looking at Legends

Comparisons	Legend 1	Legend 2	Legend 3
What was it like at the beginning of the legend?			
Where			
Main Characters			
Animals Natural/Supernatural			
Humans Special Powers			
Fighting			
What was it like at the end of the legend?			
What was being made?			

Our Solar System

Label the planets in our Solar System

_____ ○ 248 years*

_____ ○ 165 years*

_____ ○ 84 years*

_____ ○ 29.5 years*

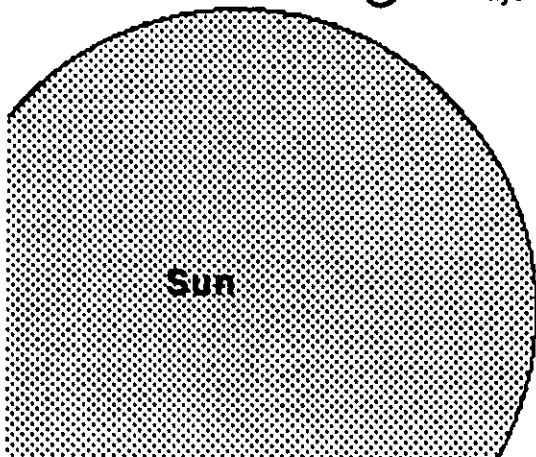
_____ ○ 11.9 years*

_____ ○ 687 days*

_____ ○ 365 days*

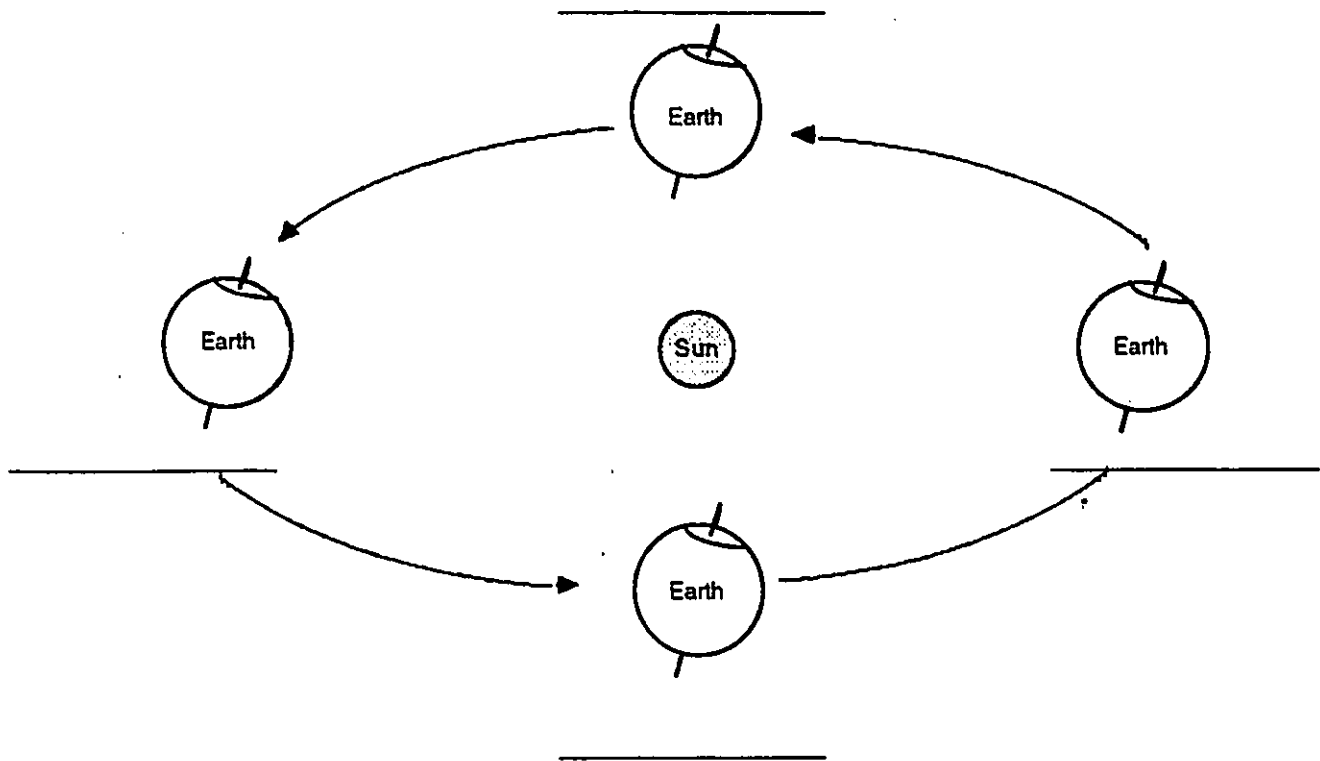
_____ ○ 225 days*

_____ ○ 88 days*

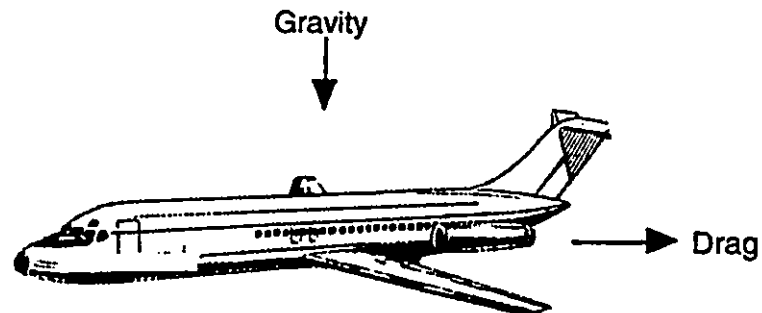


*The time required for the planet to orbit the sun once.

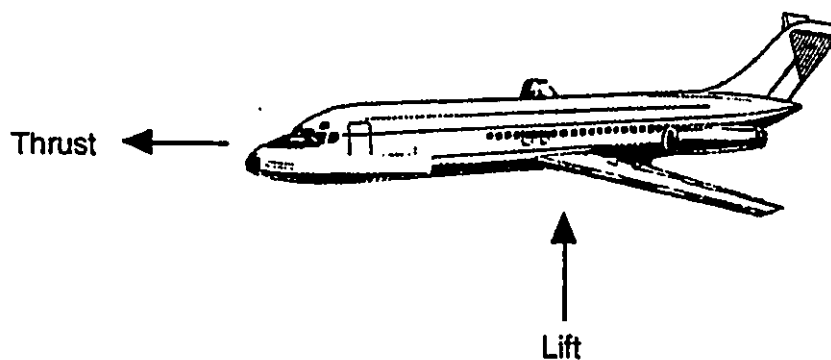
Appendix 4



Forces Opposed to Flight

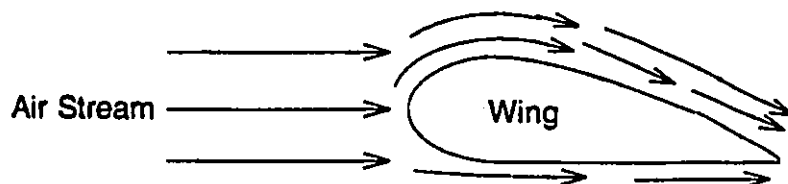


Means to Overcome the Forces Opposed to Flight



The Air Foll (Wing)

The faster air travels the less pressure it exerts. The air travelling over the curved surface of the wing, travels further and faster and exerts less pressure. This creates lift.



Air travelling along the flat surface under the wing, moves slower and exerts more pressure. This also creates lift.

Appendix 6

REACT METHOD OF RESEARCH

Select a topic.

Brainstorm what is already known about the topic.

Put down what is known in point form, four words or less, in green noteboxes. Green noteboxes are made from ruling sections on green paper (21 cm. x 28 cm.) approximately 5 cm. by 3 cm.

Make headings for the known knowledge. Cut and then paste the green noteboxes under the appropriate headings.

Read about the topic from other sources. In order to make a Bibliography make a note of the sources. For each source, write down the author, copyrite date, title, place of publication and publisher in order to make a bibliography.

Write down new information gained in white noteboxes, the same size as the green noteboxes.

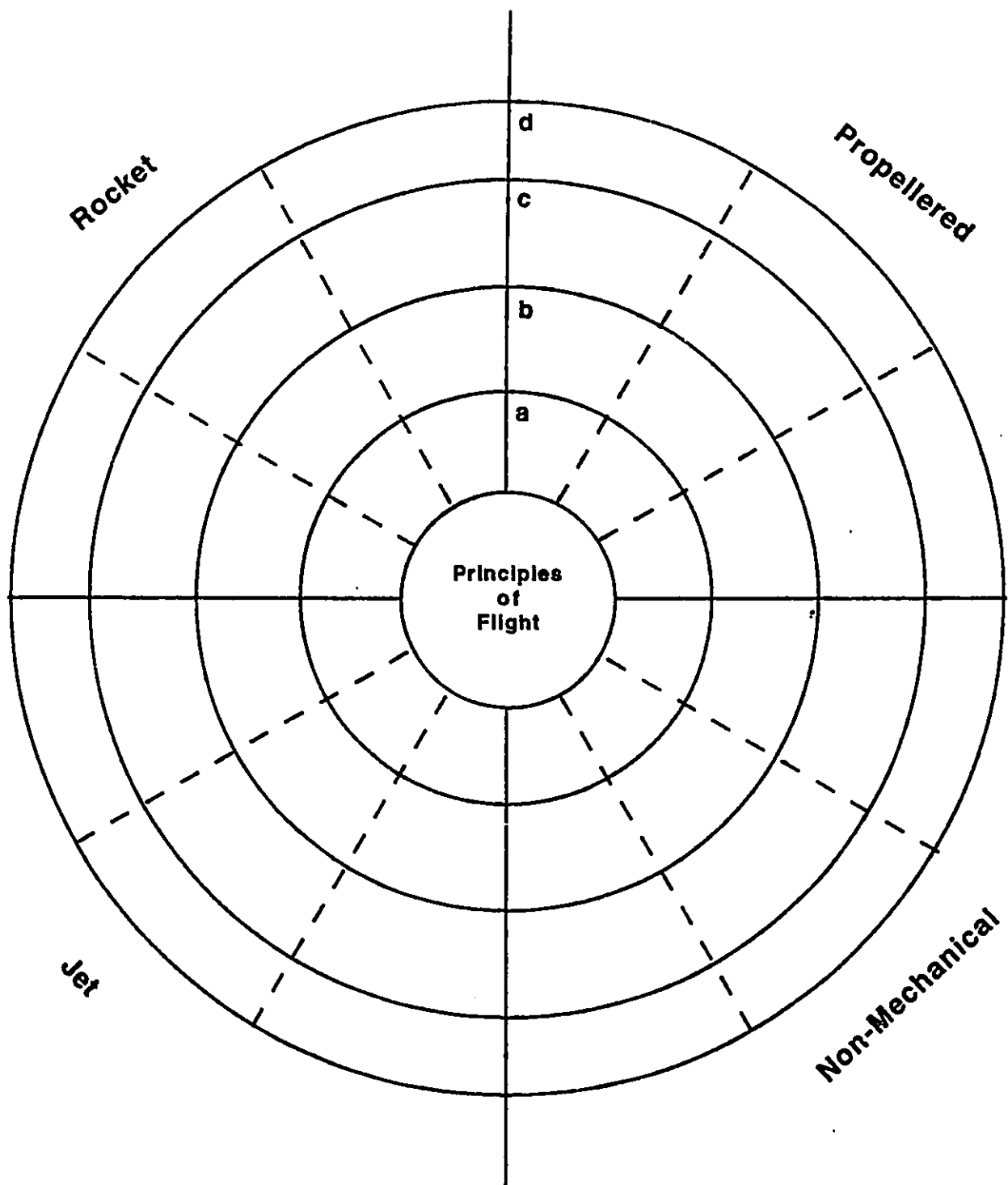
Cut and sort the white noteboxes and paste them under the green noteboxes under the appropriate headings.

Continue until sufficient knowledge is obtained.

Using the information under each heading in the noteboxes, write a written report, make a poster or create a booklet .The information under each heading may have to be reorganized to make sense.

Make a bibliography.

Adapted from Halliday (1986)



Colour code the common features:

- a) Take Off (red)
- b) Structural Influence (blue)
- c) Atmospheric Effects (pink)
- d) Landing (yellow)

Hot Air Balloon Instruction Sheet

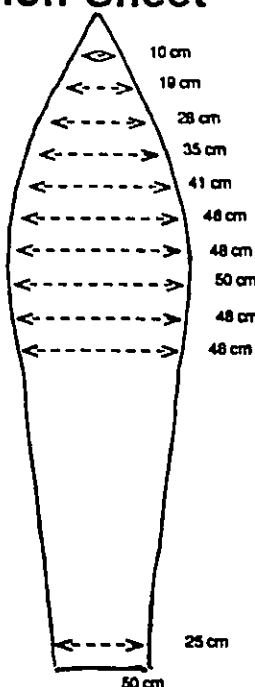
Template:

Material Required

Heavy brown kraft paper at least
50 cm wide by 240 cm long

Template Shape

Full width measurements
are given at 15 cm intervals



Balloon Construction:

Materials

24 sheets tissue paper (8 sheets each of
3 different colours)
white glue
basket weaving reed (160 cm) or string
stiffened by wrapping with tissue paper
and covering with white glue.

Method:

Note:

All glued edges should overlap by 1-2 cm
There must be no air holes in glued edges

- Join three sheets of tissue paper together as shown in diagram.
- Repeat to form 8 panels.
- Place the panels one on top of the other.
- Place the template on top of the stacked panels.
- Trace the template shape onto the first panel.
- Cut all eight layers at the same time.

Assembly:

Place panel 2 on top of panel 1. Carefully glue the right hand edges together.
Place panel 3 on top of panel 2. Carefully glue the left hand edges together.
Place panel 4 on top of panel 3. Carefully glue the right hand edges together.
Place panel 5 on top of panel 4. Carefully glue the left hand edges together.
Place panel 6 on top of panel 5. Carefully glue the right hand edges together.
Place panel 7 on top of panel 6. Carefully glue the left hand edges together.
Place panel 8 on top of panel 7. Carefully glue the right hand edge of panel 8 to the left hand edge of panel 1
(This is accordian fashion.)

- When glue is dry, hang the balloon from the ceiling and attach the reed (or string) ring to the open bottom of the balloon by rolling the tissue around the ring.

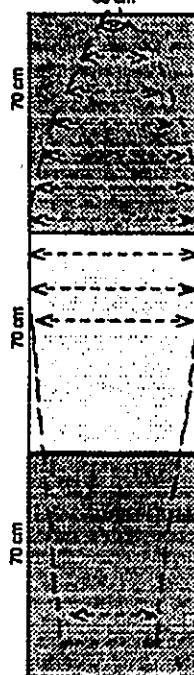
To Set in Flight:

Materials Required:

Metal stovepipe 2 feet long
Coleman Stove

- Place stove pipe over flame of Coleman stove. Hold balloon by ring over the pipe. It will gradually fill with air.

When completely inflated release.



APPENDIX D
TIMETABLE FOR DATA COLLECTION

TIMETABLE FOR DATA COLLECTION

Monday	Tuesday	Wednesday	Thursday	Friday
JANUARY 6	7	8	9	10
Interview 1 Grade 4 13	Interview 1 Grade 4 14	TEACHER PLANNING 15	Interview 1 Grade 5 16	Interview 1 Grade 6 17
Observation PA Grade 4 20	Observation PA Grade 5 21	SKI DAY 22	Observation PA Grade 6 23	24
Observation PA Grade 4 27	Observation PA Grade 5 28	SKI DAY 29	Observation PA Grade 6 30	31
FEBRUARY 3	4	SKI DAY 5	6	7
TEACHER PLANNING 10	Interview 2 Grade 4 11	Interview 2 Grade 4 12	Interview 2 Grade 5 13	Interview 2 Grade 6 14
Observation SS Grade 4 17	Observation SS Grade 5 18	Observation SS Grade 6 19	20	21
Observation SS Grade 4 24	Observation SS Grade 5 25	Observation SS Grade 6 26	27	PD DAY 28
MARCH 2	3	4	5	6
Interview 3 Grade 4 9	Interview 3 Grade 4 10	TEACHER PLANNING 11	Interview 3 Grade 5 12	Interview 3 Grade 6 13
JUNE Interview 4 Grade 4 1	Interview 4 Grade 4 2	Interview 4 Grade 5 3	Interview 4 Grade 6 4	5

PA - Lesson Segment One - Properties of the Atmosphere

SS - Lesson Segment Two - Solar System

Teacher Planning for the teaching of Segment One - January 15 - afternoon

Teacher Planning for the teaching of Segment Two - February 10 - all day

Teacher Planning for the teaching of Additional Curriculum - March 11 - all day

APPENDIX E

SAMPLE OF CODES APPLIED TO EACH OF FOUR INTERVIEWS

Sample of Codes Applied for Each of the Four Interviews for Two Students

Student	Interview 1	Interview 2	Interview 3	Interview 4
Grade 4 Subject #20	1. DFR MCP 2. PTW PLB 3. CHS	1. DFR 2. PTW PSE 3. CHS MCP 1. DFR MCP	1. DFR 2. PTW PNT PDW 3. CHS 1. DFR DIM 2. PSS PTE PRI PRC PSD PMC 3. CRL CDM MCP	1. DCP DTE DFO DSD DOS 2. PSS PTE PSD PRI POS PRC MCP 3. CRL CDM 1. DCP DRI DFO DOS 2. PSS PRI POS PFP 3. CRL CDM
Grade 6 Subject #14	1. DKN 2. PTW PWC 3. COS	1. DFO 2. PTW PDW 3. CRL 1. DFO	1. DFO 2. PTW PGM 3. COS 1. DIM DTE DFR 2. PTW PGM 3. COS	1. DIM DSD DFO DTE 2. PTW PNT 3. CRL 1. DIM DRI DFO DPP 2. PTW PRI POS MCP 3. CRL

APPENDIX F
PLAY STRUCTURE REPORT



Ramsayville



PUBLIC SCHOOL

3435 Baseline Road Ramsayville, Ontario KOA 2Y0 Telephone: 521-5922

REPORT

Use of Play Structure

Background

On the morning announcements, Mrs. Crippen said that the primary students could not play on the big monkey bars. In our class, Vanessa Cates said that we should be allowed to play on them because the older grades did not use them. So we decided to study the problem.

Information Collected

We have collected data on fifteen recesses. There have been two grade fours that have played on the monkey bars for two recesses and one grade five that went on them for one recess.

Mr. Rick Jadowski from the Gloucester Parks and Recreation Department came to Ramsayville School to check on the safety of the bars. He used a book called Guidelines on Children's Playspaces and Equipment from the Canadian Standards Association to answer our questions. He told us that we could go on the monkey bars only if we could get twenty-six more centimetres of washed sand and take a rough spot of cement off the bottom of the fire pole. He also said that the students should only hang underneath the monkey bars and not crawl or walk on the top of them. A teacher or adult should be there to supervise.

Recommendations

From our study, we recommend that the monkey bars should be opened for grades 1, 2 and 3 because the older grades are not using them very often. But before they are opened the recommendations of Mr. Jadowski must be completed. Also, Mrs. Crippen should tell all the students that they cannot crawl or walk on top of the monkey bars. They are only made for crossing or hanging underneath.

Vanessa
Jason S. *Matthew* *Ben* *Julian* *Kyle* *Heather*
Katelin *Katie* *Shannon* *Mark* *Tamara* *Crystal*
Kathleen *David* *Debra* *Jason* *Vanessa S.*
Grade 2