THE EFFECT OF LEARNING A SECOND LANGUAGE ON SIXTH-GRADE STUDENTS' ABILITIES TO UTILIZE THE PROBLEM-SOLVING PROCESSES IN SCIENCE

MICHEL PIERRE GENEST

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BY

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ABSTRACT

This study is aimed at establishing theoretical and empirical bases necessary for the elaboration of an instructional model that would capitalize on second language learners' strategic skills in communication to enhance their problem-solving abilities in science. An analysis of selected quotations from psycholinguists and science educators dealing specifically with the mental processes involved when engaged in second language learning and problem-solving respectively, revealed that there are definite similarities in reasoning patterns between these two actitivities. As part of this research, a null-hypothesis was tested to test whether an intense second language learning experience, such as offered by the French Immersion program, would enhance children's abilities to solve problems in science.

Fifty-four sixth-grade students participated in the study. Half the group were students selected from the French immersion stream and the other half were selected from the regular unilingual stream. A limited control over I.Q. and socio-economic level was exercised. The two groups were administered a twenty-six-item criterion-referenced test.

The multiple choice items were designed to measure the degree to which students develop processes of science in the elementary levels grades 4, 5, and 6.

Results indicated that there were no significant differences in achievement between the two groups. The results were interpreted in light of the design limitations. The discussion that followed served to establish a theoretical framework needed to elaborate an instructional model aimed at promoting children s transfer of strategetic skills from second language learning to problem-solving. Based on the use of metacognitive strategies, such a model when properly implemented, could have bi-directional positive effect on the children's mastery of both subjects.

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CHAPTER I

INTRODUCTION

Purpose

The main purpose of this study is to propose a theoretical foundation for the exploration of second language learning as a means to enhance students' abilities at solving problems in science. Evidence to support the validity of this foundation was gathered by synthesizing theoreticians' views on 1) the processes of language learning and 2) the processes of problem-solving in science. Existing similarities between the two sets of mental processes were then highlighted.

To further support an argument for the elaboration of such a model, a criterion-referenced test aimed at evaluating elementary students' progress with regard to the use of the process skills to solve problems in science was administered to two groups of sixth-grade students. One group consisted of bilingually educated French immersion (FI) students who have been in the program since kindergarten and another group was made up of regular stream students for whom English was the language of instruction. The average scores of the two groups were then compared to determine if there was a difference in their abilities to solve problems in science.

French Immersion Programs Defined

In Canada the term "immersion" refers to programs in which instruction is given in French during all or part of the school day to students whose mother tongue is English. "Early" means that the process of immersion starts when the student is in Kindergarten. Late would signify that the student began the program in grade 7. The aim of this program is communicative competence in the French language. Its main characteristics are (1) that the language of instruction is incidental to educational content, (2) that children learn the second language in a natural manner in their daily interactions with French speaking teachers and through subject matter taught in French, and (3) that the introduction of classes in the mother tongue is done gradually until the percentage of instructional time in both languages is balanced.

Statement of the Problem

The problem was to provide theoretical arguments and empirical evidence that learning a second language has parallels with the active strategic processes the children experience when solving problems in science. The working hypothesis was stated as: Children who attend an early French immersion program develop an enhanced ability to use the basic and integrated processes to solve problems in science. In the null form the hypothesis is formulated as: There is no significant difference between grade six FI students and regular stream grade six students in their development of abilities to utilize process skills in science.

Rationale

Parents frequently express concerns about the effectiveness of the F.I program and its possible side effects. Their queries are directed mainly to whether their children will become bilingual at the end of the program, whether they will lose their native language and also how the program will affect their children's cognitive development. McEachern (1980) did a survey of parental attitude toward the FI program. In his concluding statement, he remarked: "...it would seem that there is a general malaise felt by parents of English language kindergarten children with respect to the overall growth of children in French immersion" (p.246). According to Cummins (1980) of the Ontario Institute for Studies in Education, few programs started in Canada have been evaluated more thoroughly than the immersion program.

McEachern (1980) holds the educational community responsible for presenting information to parents on the success and opportunities of the FI program. The present research is meant to provide information on the effect of the program on the children's ability to solve problems in science. The results of this research will provide the concerned population additional information on which to base their decision when considering a French immersion education for their children.

This study was also brought about by researchers interested in knowing more about the effect of second language learning on children's academic abilities. Lapkin, Swain, and Shapson (1990) established an agenda of research in French immersion for the 90s. Three of the areas they identified are pertinent to this study. One area is concerned with cognitive effects; researchers are challenged to determine the cause of the bilingual's enhanced ability at solving cognitive tasks. Members of the the linguistic community wonder whether it is that bilinguals solve cognitive tasks differently or that the advantage is due to a higher rate of cognitive development engendered by their second language learning experience. Lapkin, Swain, Shapson (1990) stress that research in the area of cognition should focus on process rather than on product variables.

Another area for further research is concerned with French achievement. Researchers are called to gather information with regard to the processes underlying the acquisition of French in an immersion context.

Calls for research in the areas of achievement in subjects other than English or French are also presented on the agenda. The particular question posed is:

> *Do certain subject areas lend themselves more readily than others to being offered in the second language in terms of content learning, second language learning, and the integration of content and language?" (Lapkin et al., 1990, p.643).*

The present study will suggests that processes of science and language learning are very similar. Arons (1990) predicts enhanced facility of interdisciplinary transfer of skills if a child is simultaneously exposed to the same mode of reasoning in different subject areas.

It is highly recommended by some science educators that the processes be taught in the science classroom. Tobin and Capie (1982) studied the relationship of nine types of academic engagement and integrated process skills achievement. The categories of these engagements were: attending, recalling, collecting, comprehending, quantifying, planning, generalizing, non-cognitive and off-task. (Tobin and Capie, 1982). They found that attending and generalizing, together with formal reasoning ability, were related to process skills achievement and retention. They invite researchers to further explore this field.

The modest contribution of this research will hopefully trigger more discussions focused on understanding what children do when they learn a second language.

CHAPTER II

REVIEW OF RELATED EMPIRICAL AND THEORETICAL STUDIES

"They make predictions, confirm or reject hypotheses, correct, and continue." (Courtland ,1991).

One might assume that these words were written by a science educator to describe some of the mental processes children use to solve problems in science. They were, however, written by a language educator who reviewed psycholinguistic literature. Psycholinguists are concerned with the relationship between messages and the human characteristics of those who create and interpret them. They study: a) the mental processes speakers or writers experience in their attempt to convey intentions via a code, and b) the subsequent decoding processes listeners or readers experience in their attempt to assimilate the sent message.

A literature review usually serves the purpose of establishing both theoretical perspectives and empirical findings in the researcher's particular field of investigation. The present researcher will abide by this tradition in presenting a conventional literature search in part I but will also digress slightly from the standard format in presenting a part II. This is necessary because of the more theoretical than empirical nature of this investigation. The literature search in part II will be an intrinsic part of hypothesis testing for this study. It will attempt to assess the theoretical validity of using the second language learning processes as a tool for the enhancement of children's skills at using the scientific processes.

The second part of this literature search will be aimed at verifying the similarities between two seemingly different learning activities. This will be done by semantically analyzing theoretical publications in the respective domain of second language learning and science process skills. Via a mapping process the similarities will be highlighted.

Literature Review Part I

Science process skills - prerequisite to reading?

A work that closely resembles the present study was done by Merricks' (1975). This research was concerned with the possible enhancement effect of learning science process skills on reading ability. Merricks' review of literature revealed the general opinion that the learning of science process skills should enhance the reading ability of children. Merricks went on to establish a theoretical relationship between science and reading. She listed all the basic skills needed to master a reading activity and compared them to the skills chidren would exercise in a process-oriented science class. In a process-oriented environment, children would manipulate concrete objects in order to acquire the skills of a scientific investigator. Merricks suggests that learning science processes helped to establish good reading habits.

Merricks discovered that grade one students who followed a prescribed science component curriculum which consisted of a combination of ESCS (Elementary Science Curriculum Study - a process-based science curriculum) and SRM (Selected Reading Material - reading material selected by the investigator relevant to the topics and activities of the ESCS kits) achieved significantly better on the Gates-MacGinitie Reading Test than grade one students who were instructed with ESCS alone, SRM alone, or were not given any special instruction. She also discovered that the group instructed with ESCS alone did significantly better than the SRM or control group. The trend was not, however, observed at the grade 3 level. She surmised that learning the science process skills had more influence on the children's reading skills at an earlier age than at a later stage.

Merricks' work thus suggests a close relationship between a component of language learning, namely reading comprehension, and science process skills. The present research is similar in the sense that it seeks to make the connection between language learning and the aquisition of science process skills. It differs in that it seeks to provide evidence that a form of language learning, namely second language learning, has developmental potential for enhancing children's skills at using the the processes of science. In a certain way it is the reverse of Merricks' position.

<u>Learning a second language - Effect on cognition</u>

Tucker (1991) and Kessler & Quinn (1980) reviewed literature on the effect of bilingualism and second language learning on cognition. They report that the early literature, particularly before the 1960s, warns of the risks involved in educating a child bilingually. The research produced theories which claimed that psychic energy used up by the bilinguals in their attempts to master the language was done at the expense of the mother tongue and other skill development. Bilingualism was associated with mental confusion, language handicap, retardation of conceptualization, and schizophrenia, not to mention a label of being morally untrustworthy.

Contemporary researchers claim quite different associations with bilingualism than earlier studies. Most contemporary researchers claim that the process of learning a second language enhances the learner's cognitive growth (Ben Zeev, 1972; Cummins, 1983; Kessler & Quinn, 1987; Malakoff,1988; Lambert 1990). Similar findings were reported in nine different countries.

The earlier studies were criticized on their methodology. They were based on experiences in the United States which dealt with immigrants learning English. The conclusions were found later to be related to other factors, such as SES, adapting to a new environment, etc., rather than to the fact of being bilingual. Tucker (1991) noted that in a large number of cases little attempt was made to assess the proficiency level of the "bilinguals" under investigation.

The "negative" reports were also examined from a pedagogical point of view. Contemporary researchers considered the pedagogy of instruction for the "bilingual" as being of the "subtractive" type. Lambert (1975) proposed the notions of "subtractive" and "additive" bilingualism. Subtractive bilingualism is a linguistic setting in which the learning of a second language occurs at the expense of the mother tongue. The learners find themselves "submersed" in a foreign language while not nurturing their native language (L1). They attempt to conceptualize i.e., use the language as an instrument of thought, with initial access to very little foreign language vocabulary. It is reasonable to assume that under these conditions a slowing down of the cognitive growth could result.

"Additive" bilingualism, on the other hand, refers to the learning of L2 under optimum conditions when the cognitive growth of the student is actually enhanced by becoming bilingual. This phenomenon, however, occurs only in a very few cases. Research has not yet explained how or why it does occur. The French immersion program is a good example of an attempt to provide this kind of "additive bilingual" educational setting. In this program children learn a second language while nurturing their mother tongue.

Researchers are now, however, acknowledging possible detriment to French immersion students' learning of subject area content. Trade-offs may lead to students' suffering of content lag in some subject areas. In an attempt to explain why some students could benefit from a bilingual education experience and others could possibly suffer some negative consequences related to curriculum content, Cummins (1978) proposed the `threshold hypothesis':

> *The threshold hypothesis proposes that the cognitive growth and academic effects*

> *of bilingualism are mediated by the levels of competence which the bilingual child attains in L1 and L2.* (Cummins 1978, p.858)

The hypothesis further suggests that the child must attain a minimum level of competency in the second language in order to avoid cognitive disadvantage and, conversely, must attain a higher minimum level in order to benefit from the positive effects of bilingualism. Cummins (1978) claims that most of the earlier studies, proposing the negative impact of bilingualism on cognition, were carried out with children learning in a "subtractive" linguistic environment, whereas the more recent studies involved subjects "immersed" in a language program - an "additive" bilingualism context.

Carey (1984) does not deny the possible existence of a relationship between bilingualism and cognitive enhancement. Carey claims, however, that there are no studies showing "positive" results which cannot be challenged on grounds of student selection, parental and teacher attitudes or socio-economic status. He recommends that more research needs be done in order to establish a definitive relationship between second language learning and cognition.

The dispute over the influence of bilingual education on cognition seems to center on the ability to conceptualize (declarative knowledge).Concepts, events and facts we know about are classified as declarative knowledge. The focus of this study, however, is concerned with the influence of L2 learning on procedural knowledge. Procedural knowledge is concerned with skills and processes that we know how to perform; it is best learned by observing an expert model and practicing often, accompanied by feedback (Gagné 1985).

Thompson (1990) conducted an interview study among secondary school students to assess their understanding of science processes. His findings revealed that some students may not be able to explain what the science process skills are but are nevertheless proficient at using them. Jacob (1991) prepared a report on the evaluation of the progress of sixth-grade students in using the process skills to solve problems in science (**Newfoundland and Labrador: A Report of 1990 Elementary Science Assessment**). He reports that the students, even though they were not given formal instruction in the integrated processes, did better than anticipated on questions involving integrated processes. It would thus be reasonable to suggest that a deficiency in declarative knowledge does not automatically imply a deficiency in procedural knowledge.

<u>Positive effect of L2 learning on problem-solving ability in science</u>

The hypothesis of this study emanates most directly from the theoretical framework as constructed by Kessler and Quinn (1980). They have tested the following hypothesis:

> ...*additive bilinguals [having learned a second language without loss to the first] taught how to approach the discrepant situations presented in science problems will experience greater gains in their hypothesis quality and linguistic complexity scores than their monolingual peers.* (*Kessler and Quinn, 1980, p. 299*).

The subjects for their experiment were sixth-grade students. Two groups were monolingual English-speaking (a control and an experimental group) and two other groups were Spanish-English bilinguals. The Hispanic-American students were compared with much higher SES white monolingual English-speaking pupils. The experimental monolingual and bilingual groups were instructed on methods of science inquiry through films and discussions of physical science problems. The students were asked to write as many hypotheses as they could to lead an investigation of the problems presented. They were then to use Quinn's Hypothesis Quality Scale (1971) to evaluate their hypotheses and to improve their formulation, if need be.

At the end of the training sessions, the children were presented with additional film sessions and were asked to write as many hypotheses as possible (within the allowed time limit) that could reasonably lead to an investigation to solve the problems presented. The hypotheses were scored for quality and syntactic complexity. The same films were presented to the control groups who were also evaluated on the same criteria.

The results showed that the English monolingual experimental group (given instruction in science problem-solving situations) scored significantly higher than the monolingual control group in the quality of their hypotheses and in the syntactic complexity of the written language to express them. The instructed bilinguals of a low SES generated hypotheses of a much higher quality and complexity than did the bilingual control group.

More relevant to the present study is the comparison between the achievements of bilingual and monolingual groups. The mean score of the control bilingual group was slightly above that of the control monolingual group. Both experimental groups showed significant gains ($p < .001$) as a result of having been instructed to formulate hypothesis. The gain, however, for the bilingual group was "...far greater than that for the monolingual [group]."

The results pertaining to the complexity of the language used to express the hypotheses are also interesting. Scores on the complexity of language for the monolingual control group were slightly higher than the scores attained by the bilingual control group. Both experimental groups showed significant gains ($p<.001$) in the complexity of the language used to express their hypotheses; of the two, however, the bilingual group scored higher. The researchers found that there was a high correlation between scores on hypothesis quality and syntactic complexity suggesting the following "... the cognitive ability to formulate scientific hypotheses and the linguistic competence to express them involve some of the same underlying organizing principles.". This is an interesting observation that tends to provide evidence supporting the present working hypothesis.

The present study differs from Kessler and Quinn's in that it does not provide training aimed directly at outcomes to be tested. All the students will have been instructed with the same regular elementary science curriculum. This study is also not limited to the examination of ability to formulate hypotheses. It focuses on the students' abilities to use, in general, all processes - basic and integrated. It is aimed at determining whether there is a significant difference in general abilities to use the processes in science between a group of monolingually and a group of bilingually educated grade six students.

Problem solving in language

Problem solving is simply defined as figuring out what to do when one does not already know what to do. The process demands that one thinks about a plan of attack to bridge the gap from the familiar to the unfamiliar. The investigator's plan usually consists in using certain strategies to reach that goal.

Literature on language learning abounds with terminologies used by science educators to describe the processes of problem-solving in science. The psycholinguists refer to reading as a problem-solving task. (Clark, 1977, 1978; Rickheit and Strohner, 1985; Lakoff and Johnson, 1980; Federiksen 1990). The problem-solving approach to understanding second language has developed since the use of the communicative approach to second language teaching. Problem-solving techniques to learning a second language are used at two levels: (a) in determining the meaning of an utterance - a sentence; and (b) in determining how that language works.

Researchers concerned with second language learning describe the task as one necessitating the use of communication strategies (Faerch and Kasper,1983a, Marrie and Netten, 1991, Rubin, 1975 , Stern, 1975). Communication strategies used mostly in speaking, and sometimes writing are defined as "...potentially conscious plans for solving what to an individual presents itself as a problem in reaching a particular communicative goal." (Faerch and Kasper, 1983b).

Students designated as effective language learners would, according to O'Malley and Chamot (1990), use learning and communicative strategies more than students categorized as less effective language learners. O'Malley and Chamot classify learning strategies for second and foreign language into three major types: (1) Metacognitive strategies; self-regulatory strategies in which learners think about their own thinking, and plan, monitor, and evaluate their own learning endeavors; (2) cognitive strategies ; task-appropriate strategies in which learners actively manipulate the information or skills to be learned; and (3) social and affective strategies; strategies involving interaction with others for the purpose of learning, or control over one's own affective state

(Chamot, 1990). O'Malley and Chamot's review of descriptive studies in second language acquisition led them to believe that students use learning strategies with all four language skills - listening, speaking, reading, and writing. Their findings furthermore suggest that learning strategies used in a second language appear to be the same as those involved when performing communicative and learning tasks in the first language.

Given that the strategies are the same in either first or second language learning, it would be reasonable to ask how the cognitive experience of second language learning might enhance problem-solving abilities. A plausible answer to this question can be arrived at by examining the cognitive processes involved in language acquisition and appreciating the intensity of the cognitive demand imposed on the child who is learning a second language in French immersion. Cummins (1983) contributed major studies on the educational development of children in immersion. He claims that " ... bilingual children have been exposed to considerably more "training" in analyzing and interpreting language than unilingual children" (p. 120).

Another important question that needs to be raised is: since second language learning is far from being a new discipline and its processes seem analogical to the one of solving problems, why has the community of scientific educators not capitalized on this practice to support their effort at teaching the processes of solving problems in science? One possible answer to this question is that since the problem-solving approach to understanding second language learning is relatively new, the possibility of exploring these ideas has developed since linguists started to recommend the use of communicative approaches to second language teaching. This pedagogy can be compared to the "hands-on-approach" to science teaching, a relatively new perspective, where the learners experiment with the second language. This approach has been applied particularly to the French immersion classroom, where the French language is learned as a "by-product", so to speak, of learning content. The focus is more on the message, and not so much on learning about the grammar of the language. Science educators were themselves exploring with the concept of the "hands on" approach in their discipline when the linguists promoted an experiential treatment of second language learning. Awareness and debate over the transferability of pedagogies were thus not likely to surface before thorough understanding of these new pedagogies in each discipline.

A critique of the view that children can use the problem-solving process to learn a second language is presented by Bley-Vroman (1989). He considers language as a "complicated abstract formal system, [for which] young children seem not to have the general cognitive capacity to deal with it" (p.53). Bley-Vroman thus tends toward the Piagetian theory which says that the ability to use formal thinking is restricted to children who have at least reached the puberty stage (Inhelder and Piaget ,1958). Bley-Vroman is more of the opinion that that pre-puberty children acquire a language rather than learn it. He nakes a distinction between acquiring and and learning a language, refering to acquisition as "...the unconscious internalization of knowledge" and learning as "...the conscious learning of explicit rules" (p.43). Bley-Vroman also proposes that the learners nearing adolescence would tend to lose the ability to acquire a language and start learning it via a problem-solving approach. This position would tend to support the appropriateness of integrating the two subjects of second language learning and problem-solving in science at the junior high level for the purpose of enabling the transfer of problem-solving skills from one subject area to another.

Whether the process of learning a second language at an early age is conscious or unconscious does not take away from the mental activity that children must experience in order to learn or acquire a language. The children are faced with the formidable task of communicating by discovering a language code and then using that code to formulate messages. The only probe available to them is their knowledge of the first language that can be used so as to understand the functionning of the second language.

Problem-solving processes

According to Bruner (1960) problem-solving strategies can be broken down into two basic processes: (1) hypothesis generation and (2) hypothesis testing. Writers of literature on first language learning and second language learning identify these two processes as basic to the acquisition of the four language skills (reading, listening, speaking and writing). Wardhaugh (1974) and Schickedanz et al, (1983) observed that comprehension is an active process. Understanding would challenge the reader or the listener to constantly generate hypotheses about the incoming messages. The receptive learner attempts to match these hypotheses with other linguistic cues that are available. If hypotheses turn out to be inadequate the learner readily modifies them.

Second language learning theorists describe language learning processes as hypothesis formulation and testing. Researchers Faerch & Kasper (1983) describe a model of second language (L2) learning as cognitively oriented. According to this model the learner would participate actively in communicative events establishing and testing hypotheses about L2. In the process of learning a second language, two types of hypotheses are generated: (1) about the meaning of the message, and (2) about certain aspects of how L2 works.

Conclusion

The literature search revealed that the processes of generating hypotheses and testing these hypotheses seem to be basic to learning a second language and solving problems in science. There are indications that young pupils do not understand the process that they go through when learning a second language. It may be that the young L2 learner is unconciously acquiring the language rather than using the more adult problem-solving approach to learning. The less French language proficient immersion student also risks trailing behind the regular stream student as far as content learning is concerned. The goal of this thesis is not to initiate a debate on whether the learning of a second language is conscious or not, or even whether the immersion child will be successful at learning the second language. This study is more concerned with the cognitive exercise the child goes through to acquire/learn a second language. It aims at (1) identifying the child's coping mechanism in a linguistic maze and (2) drawing out similarities between the L2 learner's communicative strategies and the pupil-scientist's strategies when solving problems. The present researcher's position can be summed up in the following way; The mere attempt at working out the rules of language, testing out hypotheses about language, rejecting and reformulating these hypotheses cannot but be helpful in sharpening the young language learner's inquiry skills.

Review of Literature Part II

Comparing science and language learning processes

"Problem-solving has long been identified as one of the basic objectives of science instruction." (Mandell,1980). The Commission on Science Education of the American Association for the Advancement of Science has recognized and categorized 11 processes considered as representative of problem-solving activity (Gagné 1970). These processes are broken down into two groups: (a) basic processes including observing, measuring, inferring, predicting, classifying, and collecting and recording data; and (b) the integrated processes including interpreting data, controlling variables, defining operationally, formulating hypotheses, and experimenting.

According to the Elementary Science Curriculum Guide (Government of Newfoundland and Labrador,1989), students in the primary grades are given the opportunity to practice the basic processes in science and the upper elementary grade students are initiated to the integrated processes. Since students in the upper elementary grades would be expected to have had ample practice with the basic processes in their primary years, it is expected that there would not be any difference between the regular and French immersion grade six students in their abilities to utilize these processes. For this reason it can be argued that focus on comparing students' abilities to utilize the basic processes is not warranted. A discussion on the similarities between basic science processes and psycholinguistic processes will nonetheless be included to provide a theoretical framework for future research in the area of science and second language education at the primary level. A stronger emphasis will be placed on the assessment of success with the integrated processes since the latter are introduced to students at the elementary level. It is assumed that the students would not, for the most part, have attained a high level of proficiency at using these higher level processes. It appears that some integrated processes such as hypothesizing and experimenting are used extensively when a language is learned experientially such as in the French immersion program. Comparison of FI elementary students' scores on the use of the integrated processes to the scores of the regular stream elementary students should thus reveal an advantage for the FI students.

The following analysis will present evidence that the basic and the integrated processes used in science are very similar to some of the strategies used by the language learner. Scientific definitions of the processes used in solving problems will be compared to enunciations from the field of linguistics describing the mental acts performed by the language learner.

Use of specific problem-solving processes

Observing

Cooke, Hoyes, and Janes (1979), authors of "Searching for Structure", a science text book for the intermediate grades define the process of observing as: "The perceiving of an object or event using any of the senses" (p.4). Obviously the second language learner's successes at decoding written or spoken messages is much dependent on attentiveness to graphic and phonetic cues. There is however more to observing than just using senses to perceive objects or events. Science educators and language experts claim in parallel statements that the pupil-scientist and the language learner both endeavor to observe objects or events from a particular perspective. Investigators' search for clues is guided by limitations imposed by their hypothesis.

The hypothesis itself is formulated to solve a specific problem. Goodman (1967), presenting a model of reading, describes this activity as a psycholinguistic game. In the third postulate of the model, Goodman describes the reader-observer:

> *Now begins the selection process. He picks up graphic cues, guided by constraints set up through prior choices, his language knowledge, his cognitive styles and strategies he has learned.* (p.135)

Similarly science educator Griffiths (1987) states:

> *...ultimately good observing is not independent of theory. Rather it depends upon the existence of an underlying conceptual base which cues the observer to see what otherwise might not be seen.* (p.9)

Admittedly, second language learners (L2) and pupil-scientists do not solve the same kind of problems. They do, however, use their senses to observe events or objects in their respective environment.

<u>Measuring or Quantifying</u>

Taken at face value the definition of measuring or quantifying accepted by science educators describes remarkably well another mental process experienced by the L2 learner in an attempt to solve communicative problems. Cooke et al (1979) define quantifying as: "Describ[ing]e or comparing objects or events according to a conventional standard" (p.5). To verify the accuracy of his written or oral production, the L2 learner necessarily refers to the grammatical code of the language studied. Rubin (1975) concurs: "The good language learner monitors his own and the speech of others. That is, he is constantly attending to how well his speech is being received and whether his performance meets the standards he has learned" (p.47).

Notwithstanding the difference in the standards used in the two disciplines, it can reasonably be inferred that the pupil-scientist and the language learner both use similar procedural knowledge when comparing data against a known standard.

Inferring

The literature on language learning abounds with references to the process of inferring as a strategy to enhance language skills. Schickedanz et al (1983); Stern (1983); O'Malley and Chamot (1990); and Goodman (1967) all agree that language learners use inferencing as a strategy to understand a text or an in-coming message or to construct grammatical rules based on observed regularities. Carton (1966) has contributed a great deal to the understanding of the role of inferencing in language learning. He observed: "Individual learners vary according to their propensity of making inferences, tolerance of risks and ability to make valid, rational and reasonable inferences" (p.18). Rubin (1975), paraphrasing Mueller (1971), describes the mental activity of the reader or the listener:

> *The good reader and the good listener can understand while paying attention to a minimum of cues. He can overlook unknown words, or can read even though focusing on content words. Such a person guesses, or makes inferences about, the meaning of words or sentence structure. A wrong guess does not disturb him, but is quickly corrected from subsequent context.* (p.18)

The essential of science educators' understanding of inference cannot be more closely related to what has just been quoted from the language learning literature. They define inferring as:

> *Drawing conclusions based on evidence that may not be directly observable. Inference goes beyond observation; it often involves a judgement that can be tested through further observations. (Elementary Science Curriculum Guide, Newfoundland and Labrador, 1989, p.19)*

<u>Predicting</u>

Contemporary lingu،sts agree on the linguistic components that compose a language. They identified six basic categories: Phonetics/phonology, morphology, syntax, lexicology, semantics, and discourse analysi~. (Chastain,1976). The language learner in a communicative environment must solve problems that are related to all these components. Goodman (1967) suggests that the reader processes three kinds of information simultaneously, namely graphic (letter symbols), syntactic (sentence structure) and semantic information. Goodman observes about the reader:

> *He predicts and anticipates on the basis of this information, sampling from the print just enough to confirm his guess of what's coming, to cue more semantic and syntactic information. (p.131)*

Comparing the mental process enunciated above to the process of predicting as defined by the science educator: "Forecasting future events on the basis of observed regularities in past events" (Cooke et al, 1979), it can reasonably be assumed that the two processes are in essence the same.

Classifying

Classifying is defined as: "Grouping objects according to directly observable properties." Cooke et al (1979). Pupil-scientists as well as language learners categorize for a particular purpose - that of solving problems. Language educators' statements clearly identify the use of this process and its purpose. Schikedanz, York, Stuart, and White (1983)'s review of literature led to the observation that many preschool and even primary students cannot segment real language into units smaller than the syllable. It follows that "[i]f they cannot do this, they cannot solve the problem of determining which of several words start with the same or with different sounds" (p.187-88). Furthermore Schickedanz et al refer to a categorization difficulty when trying to explain why young students have a problem with spelling. They state:

> *Thus, even though young children realize that spelling is related to how a word sounds, their spelling contains errors because they categorise sounds differently.* (p.196)

The process of classifying is also widely used by the second language learners. Rubin (1975), referring to the foreign language learner, concurs:

> *He attends to the form in a particular way, constantly analyzing, categorising, synthesizing. He is constantly trying to find schemes for classifying information.* (p.47)

The procedural knowledge of classifying is thus a mental process that is exercised in more than one discipline.

Collecting and Recording Data

The collection of data is certainly an activity that is familiar to the foreign language learner. The L2 learner can easily be conceived as one who collects linguistic data emanating from the environment for the purpose of analysis, synthesis and subsequent communication.

Recording scientific data, which consists of organizing information collected in such a way as to facilitate its interpretation by others, is equivalent the process of communication. Language specialists Schickedanz et al (1983) describe the communication skill as:

> *...the ability to select and organize the information that is necessary to convey so that other people know what it is we are trying to tell them. (p.189)*

The scientific community uses different words to define the communicating process but the meaning is basically the same: "describing objects, events or findings (data) so that others can know the result of observation."
(Cooke et al, 1979, p.5).

Admittedly there is a difference between the classical presentation formats of scientific data and that of linguistic data. Scientific data are usually presented in the form of tables, charts, figures, graphics, symbols, maps or mathematical equations. Linguistic data, on the other hand, are usually expressed via an oral or written form. Science educators do include the oral and prose form presentation as a valid and frequently used mode of data communication. The scientist's most frequent modes of data recording, however, are modes that are relatively foreign to children and for which they need much instruction. It demands that they let go of their usual mode of communication using oral or prose form and use aternative ways. Second language learners are used to taking alternative routes in presenting verbal expositions. The child, learning a second language, often deprived of the necessary foreign language vocabulary, will resort to creative means of communication. Second language learning researchers have identified up to ten different communication strategies used by the L2 learner. Marrie and Netten (1991) studied young FI students' speech samples to determine their use of these strategies. They have observed that some strategies are used more often than others. The communication strategies used included : approximation, word coinage, circumlocution, literal translation, language mix, foreignizing, retrieval, message adjustment, topic avoidance, and message abandonment. (Marrie and Netten, p.540). Other frequently used nonverbal communication devices include drawing, gesturing and miming. Evidently these methods are far from being similar to using tables, charts, and graphs. The inference forthcoming, however, is that the effort the L2 learner puts into conveying a message using creative alternate methods might lead to an openess toward the presentation of information using non-standard devices such as the ones exploited in science.

Interpreting data

A discussion on phonetics /phonology will provide grounds for an argument claiming that a language learner's experience of phonetics bears close resemblance to the process of "interpreting data". Phonology is the study of speech sound. The learner of a second language is challenged with a task of discriminating among sounds. Chastain (1976), referring to L2 learners, states:

> *When presented sounds unlike those of their own language, speakers tend to give those sounds first-language interpretations...They translate the unfamiliar sounds into familiar ones in order to be able to process what they have heard." (p.287)*

The language learner must also analyze an incoming message to understand it. Rubin (1979) concurs:

> *The good language learner may try to isolate these features which give him maximum intelligibility. He may develop a feeling for those phonological cues which best enhance intelligibility. (p.24)*

From the quotations presented above, it can reasonably be inferred that the language learner collects linguistic data, analyzes them, and subsequently uses his analysis to solve communicative problems. The similarity of this mental process to the activity of "interpreting data" is evident when considering science educators' definition:

> *Interpreting data is defined as using the collected results to pose possible answers to a problem. A critical analysis of the data should accompany this, before hasty conclusions are drawn. (Cooke et al. 1979 p.6)*

When science educators define interpreting data, however, they do not limit the meaning of this process to the analysis of one's production of information. They also stress the importance of being able to interpret the data communicated by other researchers. Griffiths (1987), reflecting on the "more" scientific meaning of the process of interpreting data, states:

> *In a sense ,interpreting data is the flip side of communicating. People use tables, graphs, drawings, photographs, etc. as a means of exhibiting findings as clearly as possible. From these items they extract relationships, or make it possible for others to do so. When this is done, the data are being interpreted.* (p.29)

Reading specialists claim that an individual goes through a similar process when reading. Pearson and Johnson (1972), expressing their insights about the reading process, state:

> *... we believe that a reader understands a graph, a chart, a table or a map in the same way he or she understands a passage. The underlying content - the basic concepts and propositions - is identical. (p.229)*

Controlling variables

Controlling variables means:

> *discriminating among factors that will or will not affect the outcome of an experiment, and holding all such factors constant except the one to be tested or manipulated.*
> (Cooke et al.1979, p.6)

This process is perceived by science educators as the most difficult cognitive process to activate in pupils. It is a complex process that is claimed to belong to the category of formal reasoning abilities (Yeany, Yap, and Padilla, 1986).

There are doubts as to the suitability of this integrated process skills for students in grades 5 or 6. (Good, 1977)

Two conditions need be met for the full activation of this process. The first demands that you identify all of the varaibles that you wish to either manipulate or assess in an experiment. The second requires that you hold steady, or control those things which are neither manipulated nor assessed, but which might vary and therby have an effect on your experiment.

This activity is often practiced by first or second language language learners. Language experts suggests that the language learner, when listening or reading, adopts processing strategies aimed at selecting and retaining certain aspects of language output which enables him/her to comprehend a message or a passage (Mueller, 1974 ; Wardhaugh, 1974 ; and Rubin, 1975). It thus seems that certain aspects of language are perceived by the language listener or reader as more relevant than others for the purpose of comprehending a message. Researchers have identified these factors. They include grammatical as well as social features of language. Grammatical components that facilitate the understanding of a language product include subject, verb / verb tense, and object. An awareness of social dimensions such as the context of the speech act, the relationship of the participants, the rules of speaking and the mood of the speech act contribute considerably to the listener's intelligent interpretation of a message. (Rubin 1975).

To draw a parallel between the second part of this process i.e. "...holding all such factors constant except the one to be tested or manipulated" and a linguistic mental process is not so immediately done. The "linguistic detective" (Lambert and Tucker, 1972, p.208), bound by certain social rules of conversation, cannot exactly "manipulate a variable", while keeping all others constant so as to assess the impact of the manipulation on a "responding variable". Primary FI students, however, do hold some variables constant. Noonan (1990), examining the speech profile of primary FI students, discovered some interesting patterns. For example, the grade 1 and grade 2 primary students, not being able to focus on all language variables at once, tend to :

(1) use the infinitive form of the verb for all tenses e.g., "tu mettre".

(2) use the present tense more than any other tenses.

(3) use the `il' form of the verb for all subjects, e.g., `je va', `nous va.'.

(4) simplify their verb system so that most verbs are made to fit the `er' pattern or simplify it in some other way.

(5) use `avoir' as almost a universal auxiliary.

(6) use `le' and `un' as universal articles, e.g., `un chose' and `le maison'.

Noonan noted also that there is a growing awareness as students move from grade 1 to grade 3 of how to use the more correct grammatical forms. The immersion student is also known to engage in a cause and effect game, for instance if a word/verb form, etc. does not have the effect desired, the student will change the "value" (e.g., new verb tense) of that variable in his utterance and evaluate the effect again.

One cannot claim that children consciously keep certain variables constant and manipulate others to facilitate their experiment with language. It would be more reasonable to assume that in their tendency to simplify a complex system they resort to some strategy that would seek to limit the variability of certain components of language. It is then the role of the teacher to help the learner to progressively stretch those limits to enable the learner to assimilate more of the second language.

In summary ,it can be assumed that learning a second language may enhance the learner's ability to isolate factors that help to solve a problem. The L2 learner's habit of minimizing changes in grammatical variables has also developmental potential for the skill of "controlling" deliberately which in science means "to hold constant".

Defining operationally

Jacobs in "A Report of the 1990 Elementary Science Assessment, 1990" mandated by the Government of Newfoundland and Labrador, presents an item analysis of a criterion-referenced test that was administered to all the grade 6 students of that province. The report reveals that the items on the process of "defining operationally" were perceived by teachers to be the most difficult items on the test. This process is indeed an integrated problem-solving process that is the least understood by senior students let alone upper elementary students. The lenghty comparative analysis that follows should reflect the complexity of that process. Defining operationally is defined as

> *"...provid[ing]e a precise, sometimes quantitative, statement of the conditions necessary to identify an object or event."* (*Cooke et al. 1979, p.6*).

Griffiths (1987) discusses this process in some detail. He stresses the point that: "definitions are invented as a means of facilitating communication" (p.24). He highlights the difference between conceptual definitions and operational definitions. The former refers to a theoretical construct which does not readily lead to the identification of an object or event. An atom, for instance, is a concept invented to account for and predict the chemical properties of matter. An atom has never been observed so cannot be readily identified. An operational definition is also an invention but in addition it facilitates the conduction of an experiment by providing concrete conditions for the identifcation of objects or events. For example, if one wanted to sort out soil samples according to some particular notion of porosity then this notion would be at the core of the definition. For instance a porous soil could be arbitrarily defined as a soil that retains less than 25% of its own volume in water. Such a definition would enable the identification of porous and non-porous soil samples. If the sample retained 35% of its own volume in water then it would be categorised as a non-porous or semi-porous soil.

The process of assigning a value of >8 to the pH variable for the purpose of categorizing a substance as basic would be another good example of what is meant by defining operationally. The usefulness of this definition is assessed by refering to the purpose of the investigator. It may be considered that any substance with pH below 8 is not "basic enough" for this or that parti-cular chemical reaction to occur and therefore would not be included in the chemicals considered "basic". The science educator would readily question this classifcation scheme by stressing that the accepted criteria for a substance to be categorized as a base is that its pH must be above 7. Nothwithstanding the usefulness of the definition, it can be argued that to produce this definition the process of defining opera-tionally had to be activated; a precise statement of the conditions for basicity necessary to identify basic substances was given.

This cognitive activity of arbitrarily assigning a "value" (qualitative or quantitative) to a variable to facilitate experimentation is analogous to some strategies the L2 learners use. The L2 learners seem to be cognizant of the fact that word symbols and grammatical rules are purely arbitrary inventions to facilitate communication. Ben-Zeev (1977) has hypothesized : "Having two referent symbols for most referents, the bilingual child learns early that words are not intrinsic but arbitrary." (p.1009). Her interpretation of the results obtained by seven year old children on a Symbol Substitution Test indicated: "...an understanding of the arbitrariness of syntactic structure on the part of the bilinguals" (p.1016). She found that: "They [bilinguals] were better able to treat words as deseman-ticized units within a larger syntactic code system and to change the rules of the system as the test required" (p.1016).

In any language, rules are followed to facilitate communication. Grammatical rules were invented to enable people of the same language to communicate effectively. Students of a second language must discover these rules. The FI students are well known for inventing rules to satisfy their communication needs. Interlanguage systems invented by the FI students are well known by researchers who analyze students speech patterns. This system is a transitory communication device that initally satisfies the L2 learner. Young L2 learners temporarily assign values to grammatical variables for the purpose of filling voids in their communication patterns. Noonan (1990), analyzing speech samples of primary students, found, for instance, that they use "avoir" as a universal auxiliary (j'ai fatigué instead of je suis fatigué) and they use the "il" form of the verb for all subjects. Schmidt (1990), reviewing literature on implicit learning vs. learning based on understanding, notices

> *Language learners are often said to be engaged in the sophisticated enterprise of constructing a theory of the language they are learning, starting with certain innate assumptions about the abstract representation of language, looking for certain crucial data, and adding, deleting and reorganizing rules also requiring reference to abstract structures. (p.145)*

Schmidt adds that there is a continuous debate among researchers as to whether this reasoning process goes on consciously or unconsciously. Smith and Welliver (1990) in their attempt to measure the science process skills of students referred to the following definition of "defining operationally": "Definitions developed by the experimenter(s) to satisfy a need experienced during the planning and conduction of an experiment; definition of objects or events based on observable characteristics" p.736. Thus the role of these temporary definitions seems to be the same for both the pupil-scientist and the L2 learner. They are both trying to satisfy a need to set up standards when experimenting.

Griffiths (1987) stresses that a good operational definition enables one to distinguish examples from non-examples and that it should answer questions like "Tell me how" or "Tell me what the standard is". The extent to which the L2 learners engage in the process of distinguishing examples from non-examples is reflected in Rubin (1975): "The good language learner monitors his own and the speech of others. That is, he is constantly attending to how well his speech is being received and whether his performance meets the standards he has learned " [or invented] p.47. The L2 learner's grammatical inventions are thus constantly challenged. This forces the learner to be more precise in the formulation of his rules. Any speech pattern coming from an authority (teacher or book) that does not fit L2 learners' rules are grounds for reviewing the accuracy of these rules and making up new ones that are closer to the accepted standard rules of the French language.

Griffiths (1987) does not give any indication that the process itself can be good or bad. He comments rather on the appropriateness of certain operational definitions. He claims that: "...a good operational definition makes the meaning of a given term as clear and practically applicable as possible" (p.25). The present thesis is also not so concerned with quality control. It attempts to acknowledge the L2 learner's engagement (implicit or explicit) in the practice of defining operationally terms, conditions and rules. It can be argued, however, that the L2 learner's constant fabrication of inapropriate and not so precise rules is indicative that the process of defining operationally is not properly utilized. Perhaps an intuition of the process is what can be credited to the L2 learner. Perhaps if the process was more conscious the learning of a second language would be more efficient. Marrie and Netten (1991) compared communication strategies used by the effective and less effective FI students. In their conclusion they hypothesized that "...if it were demonstrated that use of achievement strategies [a type of communication strategy] could be taught in the classroom, young EFI [Early French immersion] learners might be assisted in improving their communication skills, and perhaps ultimately, general achievement"(p.457). Marrie and Netten are also hinting at the possibility that strategies can be taught and that they might have a positive effect on performance in other disciplines.

In conclusion, the theory presented above seems sufficient to initate a debate on the generic nature of this "science" problem-solving process. It can reasonably be assumed, however, that young L2 learners do not practice this cognitive activity consciously as would science students who would have been given explicit instruction on the use of the process "defining operationally".

Hypothesizing

In the teacher's guide Searching for Structure (1979) "hypothesizing" is defined as:

> *...proposing a tentative explanation, based on previous observations, for the occurrence of a set of events... It can be a guess to guide an investigation (operational hypothesis) or accepted as highly probable in the light of established fact.* (p.5-6)

Griffiths (1987) argues that the first part of this definition is correct but he challenges the "guessing game":

> *The second part, which says it is a guess, is misleading because usually it is not. It would be more appropriate to say that some hypotheses are logical extensions of existing understanding and some are novel combinations of existing understanding, while a few, which are apparently non-logical*

> *in origin, may appear to be inspired guesses but are in fact generally the product of a period of incubation.* (p.22)

About the nature of a hypothesis in problem-solving Griffiths observes :

> *It is important to make the point that hypotheses are not proven nor disproven; rather, evidence is found which supports them or refutes them. ... a hypothesis which is supported at one point in time may be refuted by further evidence on another occasion.* (p.22)

Goodman's (1971) description of the receptive processes is strong evidence supporting the position that the process of hypothesizing in language learning is the same as hypothesizing in science problem-solving:

> *...but the efficient language user takes the most direct route and touches the fewest bases necessary to get to his goal. He accomplishes this by sampling, relying on the redundancy of language, and his knowledge of linguistics constraints. He predicts structures, tests them against the semantic context which he builds up from the situation and the on-going discourse and then confirms or disconfirms as he processes further language.* (Goodman, *1971*, p.*136*)

<u>Experimenting</u>

Experimenting is:

> *...the process of recognizing and formulating a problem, planning and conducting a test of a hypothesis and using the collected result to pose possible answers to the problem.*
> (Cooke et al. 1979, p.7)

Clearly, as Griffiths (1987) points out, experimenting necessitates the use of a number of processes such as observing, hypothesizing, controlling variables with the possible inclusion of the other processes of science. An experiment is a systematic attempt to solve a problem. The experimenter, guided by an hypothesis, organizes the data collected so as to identify a pattern in his/her observations. Based on his/her empirical work the scientist is then in a position to formulate, support or modify a theory.

In comparison, most of the L2 learners' energies are spent on experimenting with language. They test their hypotheses about language and revise them as they receive feedback from their listeners. Their goal is to discover the existing patterns of the language. Stern (1983) lists ten types of language learning strategies that he identified in 1975. One type he coined "Experimental strategy". He defined as: "a methodological but flexible approach, developing the new language into an ordered system and constantly revising it" (p.414).

There are, however, fundamental differences between the linguistic detective and the scientist. The latter is often involved in trying to make sense of a phenomenon where there can be no reliable appeal to authority.
Also, it cannot be said that children consciously experiment with their new language since they do not deliberately plan to test some specific hypothesis. In spite of these differences, since the process of experimenting in science

encompasses a number of other processes that are semantically analogous to the communication strategies, its semantics cannot readily be labelled as different from experimenting with language.

Formulating a model

Griffiths identified a twelfth process that does not appear in Gagné's (1970) list. Formulating models is defined as:

> *...devising models to describe the behaviour of something that is unfamiliar in terms of something whose behaviour is familiar ... an analogy is always involved.*
> *(Cooke et al. 1979, p.7)*

Among the learning strategies the language learner uses is that of transfer. The L2 learner carries over to his second language a linguistic model based on his first language (Rubin, 1979). The model is eventually shaped into what linguists call interlanguage (IL). This language is a creation of learners to describe to themselves the way in which the second language works and to communicate their messages to others i.e. to solve linguistic problems. This habit of refering to the first language is not always helpful to the learner. For instance in the English language some adjectives tend to come before the noun, while these same translated adjectives in the French language would be placed after the noun . For example, "It's a magical door" could be translated by the interlanguage model user as

"C'est une magique porte" . The correct translation is "C'est une porte magique". As the learners know more of the second language they readily modify their second language model so as to better predict the structure of further language use.

Black and Solomon (1987) claim that there is a direct link between analogies and models: "Analogies draw attention to some familiar object or process; out of this grows the useful theoretical model" (p.249). Researchers in the field of science education seem to use analogy and metaphor interchangeably in writing about the same concept Black and Solomon claim that metaphors are "... no more than weak and partially stated analogies." (p.250). Quinn and Kessler (1986) contrast the ability of sixth-grade students, monolinguals and bilinguals, to generate multiple metaphors. Their findings revealed that bilinguals generated metaphors more often than their monolingual peers. Such an enhanced ability should reflect in the bilinguals' abilities to use analogies in problem-solving.

This habit of trying to use a model or an analogy to bridge the familiar to the unfamiliar is almost second nature for L2 learners. Like the pupil-scientists, L2 learners resort to a better model when they realize that their old model fails to incorporate newly discovered second language morphological, phonological or syntactic rules.

Effective use of processes

A literature review should also be a balanced presentation of arguments that support and oppose the thesis under study. It would appear that the review in part II is mostly positive i.e., in support of the working hypothesis. This second part of the literature review was aimed at comparing processes in two seemingly different activities. The processes for both science and second language learning/aquisition were found to be similar.

The processes themselves are neither positive nor negative. The use of the processes, however, may result in varying degree of success in attempts to explain or understand linguistic or scientific facts. The success level in turn depends on the knowledge and abilities of the user. If observations are poor for instance, the L2 learner will receive or give a less clear message. Also, the data learners receive about the way L2 functions will either be helpful or not helpful in formulating hypotheses about L2. Inferences about meaning or about the way the language works may be positive, leading in a good direction or negative , leading in a wrong direction. Predictions can be right or wrong, both for meaning and for learning how the L2 works. Second language learners are constantly modifying their classification as they discover some classifications are right (positive) and some are wrong (negative). A student may wrongly classify all verbs as being conjugated with avoir. Linguisitic hypotheses are more or less valuable, just as is the case for scientific hypotheses. The use of all the other processes can also be assessed in light of the user's knowledge and abilities. In both activities of problem solving and language learning the more able learners will tend to use strategies or processes more effectively than the less able ones.

The purpose of this thesis is not to determine whether or not the students are successful at learning a second language via a problem-solving approach. It is more concerned with acknowledging the L2 learner's habitual use of problem-solving techniques and promoting this activity as having potential for children's development of science process skills.

Conclusion

Clearly the review of the literature in part I and II illustrates that there are many commonalities between the problem-solving processes in science and in language. By the same token the review suggests the possibility that an ability in language learning could be a predictor of an ability in science and vice-versa. The main objection to this thesis is directed toward the assumption that the children's experiential treatment of second language learning is conscious. Experts are divided on this issue of habit versus cognition. Stern (1983) claims that the different experts' positions: " ... are based on different psychological interpretations of language learning and on psychological arguments and counter-arguments" (Stern 1983 , p.289). Whether the mechanism of language learning is cognitive or acquisitive does not take away from its resembalnce to the mental gymnastic performed by the science problem-solver. Although this study does not address it, the arguments of Bley-Vroman (see p. 21) make it likely that direct instruction of process skills in both science and language and the explicit comparison and use of them by students and teachers will lead to gains in both areas.

CHAPTER III

RESEARCH METHODOLOGY

Research Design

The goal of this research is to set the theoretical foundation for the elaboration of a pedgagogy based on second language learning that would enable science students to enhance their skills at solving problems in science. The analysis of the literature focused on finding similarities between children's mental processes when solving problems in science and the communicative strategies used by children when learning a second language in a French immersion context. It was hypothesized that the congruency of language learning strategies and problem-solving strategies would be recognized by the L2 learner and thus have a positive effect on his/her abilities to solve problems in science.

A paper and pencil test on the processes of science was included in an attempt to provide empirical support for the hypothesis. This test is an abreviated version of the test prepared by the Newfoundland and Labrador Department of Education. The test is made of 26 items designed to assess children's ability to use the processes of science to solve problems.

Population and Sample

General Profile

The empirical work of this study was aimed at comparing two groups of twenty-seven grade six students on their abilities to use the processes of science to solve problems. The two groups are alike except for the language through which they received their academic instruction. One group has been in the French immersion program since Kindergarten and the other group was in the regular program with English as the language of instruction.

The population sample consisted of sixth-grade students who were tested to enroll in the enrichment program managed by the Roman Catholic School Board for St.John's. The result of the test they wrote in grade four reveals their cognitive abilities. The measure used was the WISC-R (Weschler Intelligence Scale for Children - Revised, 1974). Based on their aptitudes, children were selected to participate in this program which offers an enriched curriculum. The participants attend the Enrichment Center one day a week.

The choice of this population is rationalized by claiming practicality i.e., the WISC-R results were readily available. It is also justified in an attempt to control for 1) student's commitment, and attitude toward academic endeavors, and 2) parental support. The students who are referred to the center by their teachers are, for the most part, perceived as students who strive to do their best in school and are duly supported by their parents. Research concerned with the French immersion program has revealed that the population of French immersion students appears to be composed of the more able pupils (Carey, 1984). Carey also assessed parental attitude towards the program and found that

> *"...parents who enrolled their children in the French immersion program were themselves more interested in speaking French than were the parents who chose the English program and were more likely to be taking or have already taken French courses themselves" (p.251).*

Such an interest on the part of the parents can undoubtedly be considered as evidence that they support their children in their academic efforts.

The sample of students has been taken from three schools in St.John's. These schools offered a dual stream educational program. i.e., a French immersion program and the regular monolingual program.

<u>I.Q. Consideration</u>

From the three schools thirteen boys and fourteen girls in the French immersion program were selected to write the test. The I.Q. for these children ranged from 118 to 145 with an average of 130.1. Thirteen of them were participating in the enrichment program.

The population of the regular stream students was made up of seventeen boys and 10 girls. The range of I.Q. of the regular stream students is from 125 to 147 with an average of 135.9. Eleven of them participated in the enrichment program. A two-way t-test was employed to verify if there was a significant difference in intelligence scores. The statistics are presented in Table 1. There was no significant difference in I.Q. between the two groups ($p > .05$).

<u>Socio-Economic Status Consideration</u>

Carey (1984), in his <u>Reflections on a Decade of French Immersion</u>, states that the SES of the parents of the French immersion students is significantly higher than those of the students in the regular English program. Such a claim would justify controlling for SES. However, Quinn and George (1975) have tested the hypothesis that there would be a difference between the quality of hypotheses generated by students of different socio-economic levels. They have provided evidence that the cognitive ability to formulate hypotheses does not depend upon pupils' economic status. In light of the evidence provided by Quinn and George a tight control over the SES is unwarranted. The Blishen Socio-Economic Index for Occupations in Canada (1967) was used to ascertain that the groups were not economically disparate. For the purpose of this study, some information regarding the parents' occupations was obtained from the school records and further information was obtained via an additional question at the end of the criterion-referenced test. A two-tailed t-test was then used to ascertain if there was a significant difference in socio-economic level between the two groups. The results are presented in Table 1. There was no significant difference between the two groups ($p > .05$).

TABLE 1

Descriptive Data of the Mean Socio-Economic Level and WISC-R Score for F.I. and Regular Stream Students.

Variable	Group	Mean	S.D.	t
S.E.S.	F.I.	60.35	12.32	
	Regular	60.73	12.95	- 0.03
Intelligence	F.I.	130.33	10.16	
	Regular	135.89	7.05	- 0.95

t05, DF =52 is 2.009

Teacher experience

Ideally the average number of years of teaching experience should be the same for the FI and the regular stream teachers. However, given that the French immersion program in this province is approximately 15 years old, it was not possible to select groups of FI students whose teachers were as experienced as the teachers who taught the regular stream students. The FI teachers who participated in this project averaged a much smaller number of teaching years experience than their regular stream colleagues. The control for teacher experience was further challenged by the children's exposure to three different teachers from grade four to grade six. (The criterion-referenced test is based on items that were taught over the pupils' three years of elementary science instruction). The average teaching years experience of the grade six teachers (English stream) whose students participated in the project is no less than nineteen compared to five years for the FI teachers. Given the considerable imbalance in number of years of teaching experience between the two groups of teachers, it can be reasonably expected that if teachers' experience has an influence on students' achievement, it should favor the English stream students.

<u>Time allocation for teaching the processes of science</u>

The grade six teachers involved in this project were asked to fill in a questionnaire. The purpose of the survey was to determine if there was any difference between the amount of time the FI teachers and their regular stream colleagues spent on teaching about the complex (integrated) processes of science. Based on the the School Board's time allocation for the teaching of science, the teachers were asked to estimate the percentage of that time they actually taught science (A). Out of this estimated time, they were asked to give an approximation of the time spent on teaching about the the integrated processes (B). Lastly the teachers were to provide a breakdown of their estimated time spent on the different processes. A copy of the questionnaire can be found in appendix B.

It was not possible, however, to draw meaningful conclusions from this survey, since only a small percentage of teachers, after repeated appeal, did fill in the questionnaire. It is surmised that given the small number of teachers surveyed, participating teachers did not think the survey was anonymous enough and hence it detered them from revealing this kind of information. The results of the survey are presented in Tables 2 and 3.

TABLE 2

Percentage of allocated time spent on teaching science (A) and percentage of that time spent on teaching about the processes of science (B)

Time	(A)	(B)
Regular stream	95%	43%
French immersion	93%	38%

TABLE 3

Breakdown of the percentage of the time spent teaching about the different integrated processes of science. *

% of (B) time spent on...	Regular	French immersion
Formulating hypotheses	15%	25%
Defining operationally	10	5
Interpreting data	15	15
Controlling variables	10	20
Experimenting	30	20
Formulating models	30	10

The data presented in the Tables 2 and 3 must be interpreted in light of the fact that only 4 out of the 12 teachers involved in the project responded to the questionnaire sent to them.

* Note: The number of respondents was very small.

Instrument and Procedures

The test

An easily administered testing instrument which is appropriate for elementary age students and is designed to assess the basic and the integrated process skills and concepts was readily available. The test consisted of fourteen items aimed at assessing attitudes toward science and fifty items that measured the degree to which students assimilated the concepts taught in science and their ability to use the processes of science. Twenty-six of these items were specifically testing for the usage of process skills. All the items were of the multiple-choice type. The pencil and paper, multiple-response test, consisted of two to three items for each of twelve processes. The present research is only concerned with these twenty-six items.

This test was mandated by the Department of Education in order to monitor elementary students' progress in science. It has been administered twice, in 1987 and in 1990, to all grade six students in the province. The process items were designed to be independent of the elementary program. Some of these items, however, are related to topics studied within the elementary science program.

Implementation

Permission to use the test was granted by the Department of Education, Government of Newfoundland and Labrador. The Assistant Superintendent (Curriculum) gave her approval for testing to be conducted in the three schools under the jurisdiction of the R.C. School Board for St.John's. Cooperation of the administrations of the target schools were solicited in a personal contact and via a letter. The homeroom teachers of the selected students were also approached and asked for their cooperation. They were instructed as to the time for the administration of that test, giving them the option to reschedule the testing time if it conflicted with their students' preferred activities. Parents' consents to their children's participation in this study were obtained via a letter explaining the purpose and the nature of the study. Administrators, teachers , and parents were all assured of the confidentiality of the results. Students were made aware that the results they would obtained did not count toward their academic final mark.

The test was administered during the first week of June. This time was preferred since the students had covered most of the science curriculum by then. It was administered on two different days. One group took it in the morning at around 10:30, the other at 1:15 in the afternoon.

A pilot test was conducted to determine the amount of time needed to complete the test. The children took from twenty to thirty minutes. The administration provided an isolated area for the students to write the test. Cooperation was willingly given at all levels.

<u>Test Validity</u>

The ideal way to assess students' abilities to use the processes of science to solve problems is through an experienced science educator's interpretation of their response to questions related to their thinking patterns as they perform specific hands-on tasks. Such an approach would require setting up several task centers and individual observation for all subjects. However, the complexity of such an organization and the time restraint factor rendered this option less practical. The paper-and-pencil assessment method was thus preferred.

A committee was formed to develop the criterion-referenced test in 1987. The five members of this committee were the Director of Evaluation and Research, (now Evaluation and High School Certification), a science educator and a research specialist at Memorial University, a Science-Mathematics Program Coordinator, an elementary teacher of science, and the Science Consultant with the Department of Education. Personnel with the Division of

Evaluation, Research and Planning were also involved in reviewing the items and assembling the test.

The test items were chosen to a) match the program being taught and b) be of appropriate difficulty for Grade six students. Certain items were taken from a pool prepared by other provinces and by publishers. Some of these had to be modified to meet the objectives of the test. Others were written to reflect the content of the elementary science program (Grades 4, 5 and 6). The formulation of all the items reflects content themes studied in the program (life, physical and earth science). The process items, however, were not necessarily drawn directly from the content taught. This is a desirable feature since what needed measurement was the students' abilities to process science-related problems, not their knowledge of the elementary science content.

Prior to the final selection two test forms of 52 items each were administered to 197 students. The items were screened for flaws. When flaws were discovered, the items were either rejected or corrected. Those that behaved in an aberrant fashion were discarded.

There is always a concern when selecting an achievement measure that the difficulty level will be too low for the sample population being assessed. Given the superior ability of the students selected for the present study, this concern was well founded. Examination of the results obtained by eleven French immersion students involved in the enrichment program has revealed that the ceiling of this test could be a problem in that it may not give an accurate indication of the students' achievement levels. The average score of these eleven students was 21 out of a total possible score of 26.

Given that the elaboration of a new criterion-referenced test would have required highly technical skills and a lot of extra time, it was decided that the present test would be used. Considering also the control imposed on the composition of these items it was safe to claim that the validity of the test was fairly adequate.

Reliability

The reliability of this test was determined through the computation of an alpha coefficient. The value of the alpha of the total test based on the data obtained in 1990 was 0.81. A 100% reliable test would have an alpha of 1.00. The alpha coefficient for the process items was calculated to be 0.71. It is lower than for the whole test because this subtest contains fewer items.

The reliability coefficient is useful in assessing the the consistency of the test. Another measure that yields useful informa..on is the standard error of measurement. It reflects the likeliness that an individual's test score contains a certain amount of measurement error. Consequently the SEM would be small for a highly reliable test. SEM for the total test was found to be 3.05. In other words there is 68% chance that an individual's true score fell within an interval of plus or minus 3.05 of his calculated score. With twice the SEM, the true result could reside with a 95% certainty in the range of plus or minus 2x 3.05 = 6.1. The standard error of measurement of the scores on the process items is 2.15. It is smaller given that it has fewer item than the total test.

Based on the statistics presented including the very similar results obtained on the different items in 1987 and in 1990 the test was found to be adequately reliable.

Limitations of the Study

Language of testing

Another constraint to this study is the language of the testing instrument. Grade six students in immersion were taught science in their second language. Their lack of knowledge of scientific terminology in English could possibly have been a hindrance to their achievement on the test. It was, however, decided that to offset their lower proficiency in French than in English, and to avoid potential translation problems if a French version would have been used, that it was best to leave the test in its orignal form i.e., in English.

Teachers

An ideal sample of students would have been selected from groups taught by the same teacher. Such occurrence being rare, it was not practical to control for this variable. There were seven English stream teachers, three of whom were female. Their years of teaching experience ranged from 15 to 27. The FI teachers numbered five, three of whom were female. Their years of teaching experience were three to eight.

Gender balance

A better balance between the number of girls and the number of boys in the regular stream group would have been desirable to offset any difference in abilities between the girls and the boys. The number of candidates, however, who met the selection criteria was limited. There were 17 boys and 10 girls in the regular stream and 13 boys and 14 girls in the FI stream.

Administration time

The test was not administered to all children on the same day or during the same time of the day. Due to conflicting schedules, most of the FI students wrote the test during the first period after recess and the regular stream students wrote it during the first period after lunch. The ideal time to administer the test is during the first period after recess since children would have had a break and would not be as tired as in the afternoon. It probably did not make much difference, however, since the test was of short duration (20 minutes) and the students were fairly bright.

CHAPTER IV

RESULTS OF THE INVESTIGATION

Results and Analysis

As was submitted earlier, the purpose of the study was to propose a theoretical framework for an instructional model to enhance students' problem solving abilities in science. The validity of such a framework was tested by comparing the achievements on a problem-solving science test of grade six French immersion students to the achievements of the regular stream students. This chapter presents the findings of the study and the analysis of the data obtained.

The multiple-choice test was administered to twenty-seven children in French immersion and to the same number in the regular stream. The twenty-six item criterion-referenced test was hand-scored. Eleven of these questions were basic processes items and fifteen were integrated processes items.

To determine if there was a significant difference between the mean scores of the immersion students and those of the regular stream students on achievement on the basic, integrated, and total process items, a two-tailed t-test was employed. The results of the t-test analysis are presented in Table 4. Graphics displaying performance for the total test, basic process items, and integrated process items are

TABLE 4

Descriptive data for the mean results of FI and regular stream students

ITEM TYPE (Processes)		MEAN	STANDARD DEVIATION	t
Total	Regular	78.1%	6.9	-0.63
	FI	77.5	6.7	
Basic	Regular	87.9%	12.6	0.54
	FI	88.5	11.3	
Integrated	Regular	70.9%	9.1	-1.57
	FI	69.4	8.9	

t05, Df=52 is 2.009 (p>.05)

presented in Figure 1.

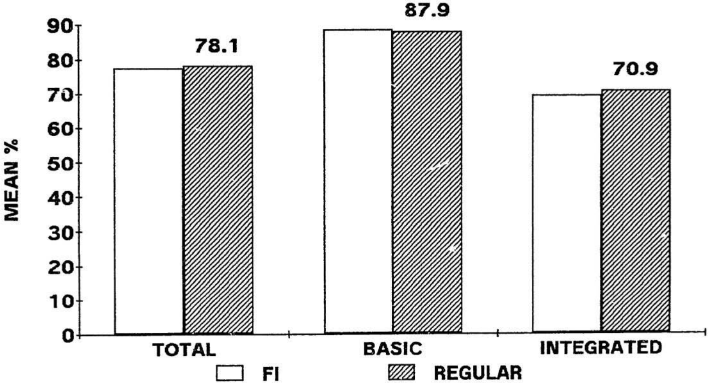
Basic processes

The results on the basic processes were consistent with what was anticipated. The students scored very high on these processes. Since these processes are part of children's general cognitive development, it is no surprise that given their grade level, they scored high and that no major difference was reported. Also, consistent with what would normally be expected, achievement on the basic processes exceeded achievement on the integrated processes.

Integrated processes

The results on the integrated processes do not support the main ·,pothesis. There were no significant differences between the achievements of the two groups ($p>.05$). While there were no significant differences in achievement on the overall integrated processes, there were some interesting tendencies with regard to the individual processes. Given that there were only two or three items per type of processes (formulating hypothesis, defining operationally, controlling variables, interpreting data, experimenting and formulating models), it was considered that a t-test would not allow meaningful interpretations.

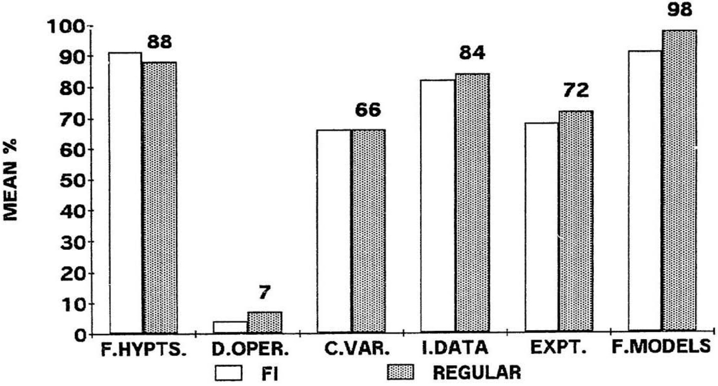
FIGURE 1. COMPARISON BETWEEN FI AND REGULAR STREAM STUDENTS



Results on "formulating hypotheses" (see figure 2) were high for both groups, confirming the concern with regard to the ceiling of the test. French immersion pupils, however, show a slightly higher performance than their regular stream peers, which FI students do most often. This is consistent with the findings of Kessler and Quinn (1980). The results obtained on the process of "formulating models" are so near the top as to be possibly attenuated by a ceiling effect. "Controlling variables" is the same for both groups. This is the most difficult, and least overtly used by the French immersion group. The regular stream students tend to be slightly higher than the FI group on the process of "interpreting data" and "experimenting". Perhaps, the difference in teacher experience between the two groups and the fact that FI students have not received any science instruction in English since Kindergarten played in favour of the regular stream students.

The single poor results obtained on "defining operationally" are consistent with the results obtained in 1987 and 1990 when those same questions were posed to all grade six students in the province of Newfoundland and Labrador. The statistical report on these earlier results points to different explanation for this phenomena: "[It] may have been the result of the quality of the items

FIGURE 2. COMPARISON BETWEEN ACHIEVEMENTS ON DIFFERENT PROCESSES



a lack of emphasis in the curriculum, or some other reason" (Newfoundland and Labrador, 1991). A close examination of one of the item, namely #11, shows that there were two possible correct answers to the question. This observation alone invalidates the item and hence does not lend itself to any serious analysis.

Gender Differences

The data lent itself to further analysis. It was used to compare achievements between genders. The 1990 Newfoundland Elementary Science Assessment and the 1982 and 1986 British Columbia Assessment revealed that there were differences in achievement between boys and girls. Contrary to previous results, a two-tailed t-test test revealed that there were no significant differences in achievement between the genders. (see Figure 3). This result could be explained on the grounds of population characteristics i.e., the population of this research was selected according to a high I.Q. criteria, while the population used in previous assessments had no such criteria. The difference in population size could also have affected the mean score. The results of the t-test analysis are presented in Table 5.

FIGURE 3. COMPARISON BETWEEN GENDERS

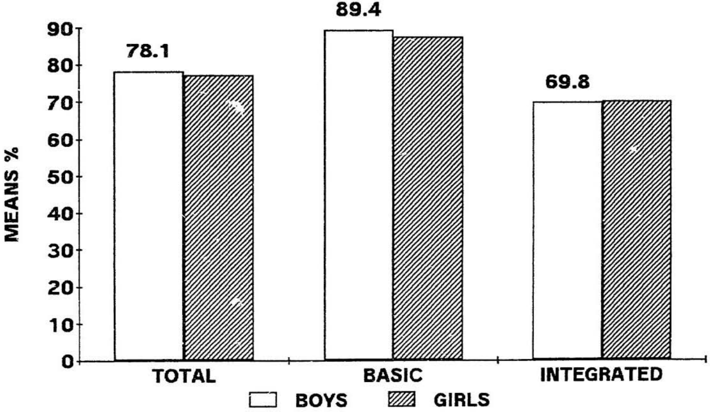


TABLE 5

Descriptive data for the mean results of boys and girls

ITEM TYPE (Processes)		MEAN	STANDARD DEVIATION	t
Total	BOYS	78.1%	7.4	
	GIRLS	77.6	9.5	0.28
Basic	BOYS	89.4%	10.3	
	GIRLS	87.5	13.8	0.57
Integrated	BOYS	69.8%	9.5	
	GIRLS	70.3	11.1	-0.19

t05, Df=52 is 2.009 (p>.05)

Conclusion

Overall, the two groups do not seem to differ in abilities to solve problems using science process skills. Due to the low test ceiling, however, the differences in ability may have been masked. The fact that the FI students did as well as their regular stream peers of the same I.Q. is, in itself revealing. Parents expressing concern over possible cognitive drawbacks of the immersion program will be reassured.

The empirical investigation did not produce evidence that tended to support the hypothesis of this thesis. Given the limitations of the paper and pencil test, however, not much importance need be attached to those results. The theoretical findings, on the other hand, tend to underline the importance of second language learning as a potential contributor to children's development of science process skills.

CHAPTER V

SUMMARY AND DISCUSSION

Summary

The goal of this study was to provide theoretical and empirical support for the suggestions that young French immersion second language learners develop more enhanced process skills in science because of their experience in learning an L2. The theoretical foundation for this proposition was obtained by comparing second language educators' descriptions of the mental tasks of learning a second language to the science educators' definition of the processes of science. The similarities and the differences between the two activities were then highlighted. Empirical support was sought by administering to two groups, French immersion and regular stream grade six students, a criterion-referenced test designed to assess grade six students' abilities to use the processes of science. The results were then compared to determine whether there was a significant difference in achievement.

Discussion

The results concerning the integrated processes do not support the main hypothesis. There was no significant difference between the achievements of the two groups, ($p > .05$). It was predicted that the FI children would have an edge over their regular stream peers when attempting to solve problems in science. The results show that the process achievement of the two groups are about the same . This observation , however, is consistent with Genesee's (1987) findings. His analysis revealed that early and late French immersion students experienced no lag in achievement in math and science as a result of receiving academic instruction in French. The theoretical discussion that follows should provide a plausible explanation for the failure of the French immersion students to outperform their regular stream peers.

There were two major assumptions on which the hypothesis of this research resided. It was assumed that training in problem-solving was occurring implicitly when students learned a second language in the immersion program. There was no mention of the need for instructions to facilitate transfer of the children's skills at solving communicative problems to the new situation of solving problems in science. The success of Kessler and Quinn (1980) in enhancing children's ability to formulate hypotheses can partly be explained by their dispensing of instructions with regard to the formulation of hypotheses. Their results showed that instructed and non-instructed bilinguals did better on their quality of hypothesis than their respective monolingual counterparts.Kessler and Quinn proposed an explanation for their observations: "The higher scores for the bilinguals suggest that bilingual children experience more fully the conceptual conflict that triggers the equilibration processes of assimilation and accomodation operative in cognitive development" (p.306). It is also possible, however, that the bilingual's ease of assimilating the procedural knowledge of hypothesizing stems from a mental readiness to recognize a thinking pattern that is already familiar . O'Malley's (1990) enunciation supports this hypothesis, he claims:

> *...strategy transfer is largely based on a pattern-matching condition in which individuals look for common stimulus features or patterns between new tasks and contexts and those included in the original learning or instruction (p.488).*

A second assumption on which this research was based dealt with the generic nature of the processes of science. This position would be not be in total disagreement with the Piagetian school of thought which promotes the idea that intellectual structures are independent of the discipline on which they operate. It would be in disagreement, however, with the suggestion that pre-puberty students engage quantitatively in processes that are labeled as accessible only by post-puberty pupils. Another school of thought promoted by Ausubel(1968) and Gagné (1977) would differ in a major way with the assumption that the processes are learned independent of the subject being studied. Ausubel and Gagné would accept the notion that pre-puberty students engage in thought processes that science educators label as complex These two assumptions would thus seem to point toward an hybridization of the two major school of thoughts on teaching and learning.

Science educators have often promoted their discipline as one where the acquired procedural knowledge enhances children's skills in other disciplines (Arons, 1990; Funk et al,1979; McLeod, et al,1975). Kessler and Quinn (1987) have claimed the same as far as language learning is concerned . They submit:

> *This subconscious experience in generating language hypotheses more extensively than monolingual peers may have a similar effect upon the ability to generate divergent scientific hypotheses of increasingly better quality.* (p.184)

If transfer of skills can occur bi-directionally then evidently there must exist thinking patterns that are common to the mental exercises in both disciplines. McLeod et al, (1975) hypothezised: "If the process skills are truly generalizable, then ability to control variables in the social sciences, for example, should predict a high score on the process in science-even if the student has not taken 'process science'" p.420..

It would seem that teachers' assistance to students in mapping thinking patterns in language learning processes to problem-solving processes in science should facilitate the students' transfer of strategies from one discipline to the other. Science taught in the context of a French immersion program should provide the ideal setting for such a transfer to occur. Arons (1990) suggests that ability to transfer is enhanced when the reasoning pattern to be learned is practiced in entirely different areas.

A new hypothesis seems to emmerge from this discussion. It appears that the enhancement of L2 learners' problem-solving skills may depend on whether they have received instructional assistance helping them to associate their L2 learning procedural knowledge to the similar knowledge involved in problem-solving.

Chamot and O'Malley (1987) proposed a program of instruction to integrate second language learning instruction with academic learning. The CALLA (Cognitive Academic Language Learning Approach) is a set of transitional instructions designed to help upper elementary and secondary LEP (Limited English Proficiency) students to acquire language skills, as well as developing a sound academic language base in science, mathematics and social studies before admitting them into the mainstream curriculum. The program is designed to teach the English language skills by referring to literature covering subject areas in science, mathematics and social studies. Chamot and O'Malley recommend that the introduction of subject area content be introduced in a particular sequence. Science is to be introduced first: "...since by using a discovery approach to science, teachers can capitalize on experiential learning opportunities which provides both contextual support and language development" (p.231). Admittedly the FI program is very close to providing an ideal setting for promoting inquiry skill transfer.

Other Plausible Explanations

The theory presented above may, for the most part, account for the fact that the FI students have not outperformed their monolingual peers on the test of scientific processes. The results, however, must be interpreted in light of some other more practical considerations. It is important to consider for instance that the language of the testing instrument was English. Given that the FI children have never been exposed to any schooling in their native language discussion related to problem-solving, it can be surmised that their monolingual peers may have had a linguistic advantage over them. Therefore, the academic language of the test may have contributed negatively to the FI students' success on that test.

Another factor related to language use which may have had a negative impact on FI students' achievement is concerned with the curriculum material used by the French immersion teachers. The curriculum material used is a translation from the English version of Addison Wesley Science. Such a translated version may have occasionally failed to convey the precise meaning of the concepts and processes to be learned.

Teacher experience may have played a more significant role than anticipated. On the average, teachers of the regular stream program are much more experienced than their colleagues of the FI stream. This influence could have played in favor of the regular stream students.

Obviously the results must also be interpreted in the light of the difference in the amount of time that the two groups of teachers have spent on teaching about the processes. Given the unsuccessful attempt to obtain this information, it is uncertain whether there is any difference between the two groups of teachers as far as time spent on science is concerned. French immersion teachers, however, must spend a good portion of their allocated time for science teaching the vocabulary relevant to a particular science lesson. It would, therefore, not be unreasonable to assume that the regular stream teachers spend more actual time doing science than their French immersion counterparts. If so, the regular stream students' longer exposure to the use of the integrated processes may have had a positive effect on their scores.

Limitations on Generalizability

The generalization of these results should strictly speaking be restricted to a certain population of students, the more able students. It can however be argued that French immersion students of lesser abilities are also using such strategies and should be quite capable of achievements that are superior to their regular stream peers of the same ability. However, no evidence here supports this assertion.

Another consideration in the interpretation of these results has to do with the difficulty level of the test items. It can be inferred, given the high score obtained by both groups that, had the items been more challenging, a more telling result would have surfaced. The outcome of such an alternate test could have led to a more meaningful interpretation.

Educational Implications

It is the position of the present researcher that FI teachers by virtue of their privileged positions as second language and science teachers, should capitalize on this set of circumstances to lead students to draw parallels between their experientially inclined frame of mind, when involved in science activities, and their linguistic detective role playing when attempting to learn and communicate in their second language. The privilege is not so readily shared by their colleagues of the regular stream. The latter deal with students that have, relative to their grade level, automatized the procedural rules governing their native language. Chamot and O'Malley paraphrasing Rabinowitz and Chi,(1987) report:

> *Learning strategies are conscious and deliberate when they are in the cognitive and associative stages of learning but may no longer be considered strategic in the autonomous stage, since the strategies are applied automatically and often without awareness.* (p.233)

Kessler and Quinn (1987) suggest that the L2 learner is constantly actively involved in resolving conflicts:

> *In dual language development, the increased demands to observe details required by language input in specific cultural contexts and the consequent increase in uncertainty in responding in specific language contexts enhances the conflict between possible linguistic hypotheses governing the two languages.*(p.184)

<u>Methodological Directions</u>

Attention should probably be turned toward teaching metacognitive learning strategies. "Metacognition refers to one's knowledge concerning one's own cognitive processes and products or anything related to them. e.g., the learning -

relevant properties of information or data" (Flavell, 1976, p.232). Chamot and O'Malley (1987), reviewing works by researchers in the field of learning strategies, state four basic assumptions:

> 1. *Mentally active learners are better learners....*
>
> 2. *Strategies can be taught....*
>
> 3. *Learning strategies transfer to new tasks. Once students have become accustomed to using learning strategies, they will use them on new tasks that are similar to the learning activities on which they were initially trained.*
>
> 4. *Academic language learning is more effective with learning strategies. Academic language learning among students of English as a second language is governed by some of the same principles that govern reading and problem solving among native English speakers.*

Chamot and O'Malley claim that research evidence supports the first two propositions but that "the transfer of strategies to new learning requires extensive instructional support" (p.240).

The promotion of the transfer of L2 learning strategies transfer to problem-solving tasks demands teacher training and modification of the delivery of the French immersion curriculum. The teachers need to acquire the skills necessary to provide metacognitive strategy instruction to French immersion students.

The implementation of a new model of instruction also necessitates the following components:

1. *Theoretical framework.*
2. *A curricular scope and sequence.*
3. *Methodological directions.*
4. *Guidelines for, or examples of, specific lessons.*
5. *Suggestions of evaluation of student achievement.*
   (Chamot, 1990) p.507.

The production of the first item on the above list has been the main concern of this research. Some methodological directions were also presented.

<u>Recommendations for Further Research</u>

1. Suggestions for research associated with this work would include testing to see whether the addition of metacognitive instruction on strategy use and transfer would enhance FI students ability to solve problems in science.

2. It would also be interesting to find out if such instruction would affect (accelerate) children's transition from concrete to formal cognitive functioning.

3. A comparative survey of French immersion and regular stream students' attitude toward science could reveal interesting information.

4. A comparative survey of ex-French immersion students' career choices might reveal something about their predisposition toward scientific-oriented careers.

5. A comparison study on children's use of analogies to solve problems in different disciplines would also be revealing.

6. A similar study with pupils of average abilities might also be undertaken.

7. A study with more examples of the integrated process skills could be undertaken, to ascertin if there really are differences between the individual processes.

8. Lastly a study of the effect of a trilingual education on cognition would be educational.

Concluding Remarks and Recommendations

In conclusion, the main objectives behind any attempt to facilitate an enhancement of the use of the processes of science to solve problems via learning a second language should be to (1) help students become aware of what they do when they learn a new language, (2) help them recognize that the strategies used in language are also used in problem-solving and (3) finally encourage them to consciously use these strategies in both disciplines.

The conscious exercise, in itself, of transferring procedural knowledge from one subject area to another could have another potentially beneficial effect on the child's cognition. It is well known that such transfer of problem-solving patterns from one academic area to another area, is responsible for many discoveries in science. Gick and Holyoak (1980) summarizing anecdotal reports of creative scientists and mathematicians remark: "...the development of a new theory frequently depends on noticing and applying an analogy drawn from different domains of knowledge" (p.306). They refer to examples such as the hydraulic model of the blood circulation system, the planetary model of atomic structure and the "billiard ball" model of gases as representing major scientific theories constructed by using analogies. Thus the child involved in this cognitive transfer activity may become more alert at observing similarities between seemingly different problems and be more open to try using solutions to solve problems in a variety of contexts.

REFERENCES

Arons, A.B. (1990). A guide to introductory physics Teaching. Toronto: John Wiley & Sons. (288-327)

Ausubel,D.P. (1968). Educational Psychology. New York:Holt,Rinehart and Winston.

Ben-Zeev, S. (1977). The influence of bilingualism on cognitive strategy and cognitive development. Child Development, 48: 1009-1018.

Black, D., Solomon,J.(1987) Can pupils use taught analogies for electric current? SSR Dec 87: 249-254.

Bley-Vroman, R. (1989). What is the logical problem of foreign language learning? In S.M. Gass S.M and J. Schachter, eds. Linguistic perspective on second language acquisition. Cambridge: Cambridge University Press. 41-68.

Blishen, B.R. (1967). A socio-economic index for occupations in Canada. Canadian Review of Sociology and Anthropology. 4:41-53

British Columbia. (1986). The 1986 British Columbia Science Assessment: General Report - A report to the Ministry of Education.

Bruner, J. (1960). The process of education. Cambridge, Mass., Harvard University Press.

Carey, S. (1984).Reflections on a decade of French Immersion. The Canadian Modern Language Review 41(2): 247-259.

Carton, A.S. (1966). The method of inference in foreign language study. The Research foundation of the City of New York.

Chamot, A.U.,and J.M. O'Malley. 1987. The cognitive academic language learning approach: A bridge to the mainstream. TESOL Quaterly 21(20): 227-249.

Chamot, A.U. (1990). Cognitive instruction in the second language classroom:The role of learning strategies. Georgetown University Round Table on Language and Linguistics 1990: 496-513

Chastain, K. (1976). Developing Second-Language Skills: Theory and Practice. Boston: Houghton Mifflin.

Clark, H.H. (1977). Inference in comprehension. In D. Laberge & S.J. Samuels(eds.) Basic processes in reading perception and comprehension. Hilldale,NJ.: Erlbaum.

Clark, H.H. (1978). Inferring what is meant. In G.Rickheit & H.Strohner (Edts.) Inference in text processing, (pp.23 -24). Amsterdam,North-Holland: Elsevier Science.

Cook, D., J.D. Hoyes, J.R. Janes. (1979). Searching for Structure: Teacher's Guide (Book 1) Toronto: Holt, Rinehart and Winston of Canada.

Courtland, M.C. (1991). Establishing a theoretical framework for language arts programs. In: M.C. Courtland and T. Gambell, eds. Curriculum planning in the language arts: A holistic perspective K-12. (In preparation)

Cummins, J. (1978). The cognitive development of children in immersion programs. La Revue Canadienne des Langues Vivantes, 34(5): 855-883.

Cummins, J. (1980). Theoretical underpinnings of French Immersion. Paper presented at Immersion '80 Conference Fredericton.

Cummins, J., (1983). Language proficiency, biliteracy and French Immersion. Canadian Journal of Education, 8(2):117-138

Cummins, J. (1980b). The cross-lingual dimensions of language proficiency: Implications for bilingual education and the optimal age issue. TESOL Quaterly, 14(2): 175-187.

Ericsson, K. and H. Simon. 1980. Verbal reports as data. Psychological Review 87(3): 215-251.

Faerch, C. & G. Kasper. (1983a). Strategies in interlanguage communication. Harlow: Longman Group Ltd. pp.1-61.

Faerch, C. & G. Kasper. (1983b). "On identifying communication strategies in interlanguage production." In: C.Faerch and G. Kasper, eds. Strategies in interlanguage communication. 210-237. New York: Longman.

Flavell, J.H., 1976. Metacognitive aspects of Problem Solving. In: L.B. Resnick, ed. The nature of Intelligence. 231-235. N.Jersey: Erlbaum.

Frederiksen, N. (1990). Measuring skills in problem solving. In Legg, S., & Algina J. (eds.) Cognitive assessment of language and math problems. Ablex: New Jersey. 43-91

Funk, H.J., J.R. Okey, R.L. Fiel, H.H Jaus, & C.S. Sprague. (1979). Learning science process skills. Iowa: Kendal/Hunt

Gagné, R.M. (1970). The conditions of learning. New York; Holt Rinehart & Winston.

Gagné, E.D. (1985) . The cognitive psychology of school learning. Boston, Mass.: Little, Brown and Company

Genesee, F. (1987). Learning through two languages. Newbury House: Massachusetts.

Gick, M.L., and K.J. Holyoak. 1980. Analogical problem solving. Cognitive Psychology 12(3): 306-355.

Good, R.G. (1977). How children learn science: Conceptual development and implications for teaching. New York: MacMillan Publishing Co.

Goodman, K.S. (1967). Reading: A psycholinguistic guessing game. Journal of the Reading Specialist, 6: 126-135

Goodman, K.S. (1971). Psycholinguistic universals in the reading process, In: Pimsleur and T.Quinn, eds. The psychology of second language reading. Cambridge: University Press.

Griffiths, A.K. (1987). The evaluation of scientific processes. Toronto: Holt, Rhinehart and Winston of Canada.

Inhelder, B., and J.Piaget. 1958. The growth of logical thinking from childhood to adolescence. New York: Basic Books

Kessler, C., & M.E. Quinn. (1980). Positive effects of bilingualism on science problem-solving abilities. Georgetown University Round Table On Language And Linguistics : 295-308

Kessler, C., & M.E. Quinn. (1982). Cognitive development in bilingual environments. In B. Hartford, A. Valdman & C.R.Foster, eds. Issues in international bilingual education: The role of the vernacular, 53-79. New York: Plenum Press.

Kessler, C., & M.E. Quinn. (1987). Language minority children's linguistic and cognitive creativity. Journal of Multilingual and Multicultural Development, 8(1,2),

Lakoff, G., & M. Johnson. (1980). Metaphors we live by. Chicago: University of Chicago Press.

Lambert, W.E.,& G.R. Tucker. (1972). Bilingual education of children:The St.Lambert experiment. Massachusetts: Newbury House.

Lambert, W.E. (1975). Culture and language as factors in learning and education. In A.Wolfgang, ed. Education of immigrant students. Toronto: Ontario Institute for Studies in Education.

Lambert, W.E. 1990. Persistent issues in bilingualism. In Harley et al.,eds. The development of second language proficiency. Cambridge: Cambridge University Press. 201-226.

Lapkin, S. and M.Swain with S. Shapson. (1990). French Immersion research agenda for the 90s. The Canadian Modern Language Review 46(4): 638-674.

Mandell, A. (1980). Problem-solving strategies of sixth-grade students who are superior problem solvers. Science Education 64(2): 203-211.

McEachern, W. (1980). Parental decision for French Immersion:A look at some influencing factors. The Canadian Modern Language Review 36(2): 239-24.

McLeod, R.J., G.D. Berkheimer, D.W. Fyffe, & R.W. Robinson. (1975). The development of criterion-validated test items for four integrated science processes. J.Res.Sci. Teaching. 12(4): 415-421

Malakoff, M.E. (1988). The effect of language of instruction on reasoning in bilingual children. Applied Psycholinguistics, 9(1): 19-38

Marrie,B. & J. Netten. (1991). Communication strategies. Canadian Modern Language Review, 47(3): 442-462.

Merricks, A.R. (1975). Science process activities, selected science reading materials and reading achievement of primary school children. Thesis. Memorial University of Newfoundland.

Mueller, T. (1971). The development of curriculum materials for individualized foreign language instruction. In H.B. Altman and R.L. Politzer, eds. Conference on individualizing foreign language instruction. Final report (unpublished)

Mueller, T. (1974). Another look at how to teach listening and reading comprehension. Modern Language Journal, 58:19-23.

Newfoundland and Labrador. (1989).: Elementary Science Curriculum Guide. Division of Curriculum and Instruction, Department of Education.

Newfoundland and Labrador. (1991).: A Report of the 1990 Elementary Science Assessment. Evaluation and High School Certification Division, Department of Education. Prepared by W.C. Jacobs.

Newfoundland and Labrador. (1992).: Profile '91 - Educational Performance Indicators (Primary, Elementary, Secondary). Department of Education, Division of Evaluation.

Noonan, M. (1990). A profile of the speech of French immersion students of grades I,II and III in Newfoundland and Labrador. Thesis. Memorial University of Newfoundland.

O'Malley, J.M. (1990). The cognitive basis for second language instruction. Georgetown University Round Table on Language and Linguistics. : 478-495.

O'Malley, J.M., & A.U. Chamot. (1990). Learning strategies in second language acquisition. Cambridge: Cambridge University Press.

Pearson, P.D., & D.D. Johnson (1972). Teaching reading comprehension. New York: Holt Rinehart and Winston.

Quinn, M.E. (1971). Evaluation of a method for teaching hypothesis formation to sixth-grade children. Unpublished doctoral dissertation. University of Pennsylvania.

Quinn, M.E. and C. Kessler. (1986). Bilingual children's cognition and language in science learning. In J.J. Gallagher & G. Dawson, eds. Science education & cultural environments in the Americas: Inter-American seminar on science education. 32-39. Washington, DC: National Science Teachers Association

Rickheit, G., & H. Strohner. (1985). Advance in Psychology: Inference in Text Processing. Amsterdam, North-Holland: Elsevier Science.

Rubin,J.(1975). What the`good language learner' can teach us. TESOL Quarterly 9:41-51

Rubin,J.(1979). What the`good language learner'can teach us. In : J.B. Pride, ed. Sociolinguistic aspects of language learning and teaching.(Chpt.2) Oxford University Press.

Schickedanz, J.A., M.E. York, I.S. Stewart, & D.A. White. (1983). Strategies for teaching young children. Englewood Cliffs, N.H: Prentice Hall. 179-244.

Schmidt, R.W., 1990. The role of consciousness in second language learning. Applied Linguistics 11(2): 129-158

Smith, K.A., and P.W. Welliver. (1990). The development of a science process assessment for fourth-grade students. Journal of Research in Science Teaching. 27(8):727-738.

Stern, H.H. (1975). What can we learn from the good language learner? Canadian Modern Language Review, 31:304-18.

Stern, H.H. (1983). Fundamental concepts of language teaching. Oxford: Oxford University Press.

Thompson, J.R. (1990). Secondary school students' understanding of science processes: An interview study. Thesis. Memorial University of Newfoundland.

Tobin, K.G., & W. Capie. (1982). Relationship between reasoning ability, locus of control, academic engagement and integrated process skill achievement. Journal of Research in Science Teaching, 19(2):113-121.

Tucker, G.R. (1991). Language planning. In: A.G. Reynolds, ed. Bilingualism, multiculturalism, and second language learning: The McGill conference in honour of Wallace E.Lambert. New Jersey: Erlbaum. 65-79.

Wardhaugh, R. (1974). Topics in applied linguistics: A new perspective on reading. Massachusetts: Newbury House.

Yeany R.H., K.C. Yap, and M.J. Padilla (1986). Analyzing hierarchical relationship among modes of cognitive reasoning and integrated science process skills. Journal of Research in Science Teaching, 23(4): 277-291.

APPENDIX A

1. Here are pictures of the twigs of three willow bushes

Which willow has leaves which are widest near the tip of the leaf?

a) plant 1
b) plant 2
c) plant 3
d) not enough information given

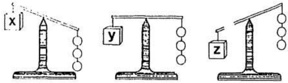
2. Look at the chart below

	Land Animals	Water Animals
Has Bones	1	2
Does Not Have Bones	3	4

In which box would you put a whale?

a) box 1
b) box 2
c) box 3
d) box 4

3. A student was asked to put boxes **x**, **y**, and **z** in order from heaviest to lightest



Which of the following shows the 3 boxes <u>from heaviest to lightest</u>?

a) x, y, z
b) y, x, z
c) z, y, x
d) z, x, y

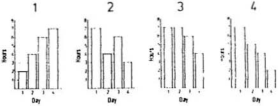
4. Jane said that if you mix 2 grams of salt and 100 grams of sugar with 1 litre of water and let the mixture stand, you get taffy, a kind of candy. The **best way** for you to test this would be to

a) search for the recipe in an encyclopedia.
b) buy some taffy and see if it has salt in it.
c) mix the salt, sugar, and water, let them stand, and then see what happens
d) dissolve taffy in water and boil away the water to see if sugar and salt are left.

5. Homing pigeons are birds that can find their way home from great distances. A man released a pigeon 30 kilometers from home. He did this four days in a row and recorded how long it took the pigeon to return home. He got these results

Day	Time
1	7 hours
2	5 hours
3	4 hours
4	2 hours

Look at the graphs below.

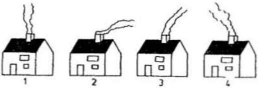


Which graph shows the results for the pigeon?

a) graph 1
b) graph 2
c) graph 3
d) graph 4

---

6. Look at the smoke from the chimneys below.



On which day was the wind the <u>strongest</u>?

a) day 1
b) day 2
c) day 3
d) day 4

---

7. You want to find out which type of paper towel soaks up water fastest. You plan to dip one piece of each towel in a dish of water. What condition must be kept the same in this experiment?

a) the size of the dish
b) the colour of the paper towel
c) the time the towels are in the water
d) the amount of water in the dish

A piece of pond weed was placed in water and a light was shone on it from a distance of 20cm. The weed gave off bubbles of oxygen, and the number of bubbles per minute were counted. The experiment was repeated with the same light at 30cm, 40cm, 50cm, and 60cm from the weed.

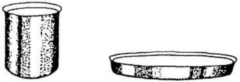
The results are shown below

Distance (centimeters)	20	30	40	50	60
No of bubbles/min.	180	160	140	120	100

Which hypothesis do these results support?

a) The nearer the lamp, the fewer bubbles produced.
b) The further away the lamp, the fewer bubbles produced
c) The further away the lamp, the more bubbles produced.
d) The distance has no effect on the number of bubbles produced.

9. Equal amounts of water were poured into the two containers shown below.

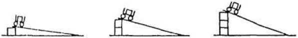


1 2

If both containers are placed in the sun for a period of two hours, we might expect to find

a) less water in each container than in the beginning, but still equal amounts of water in container 1 and container 2.
b) more water in container 2 than 1.
c) more water in container 1 than 2.
d) the same amount of water in each container as there was in the beginning.

10. The following diagrams show a test you can do with carts on slopes. They are all set up on the same kind of surface.



1 2 3

Which hypothesis are you testing?

a) Loaded carts travel further than empty carts.
b) The higher the ramp, the further a cart travels.
c) The bigger the wheels, the further a cart travels
d) The bigger the load, the further a cart travels.

11. Which of the following is an **operational (working) definition?**

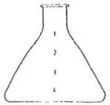
a) Rowing - propelling a boat through water.
b) Ice - a solid form of water
c) Oxygen - a colorless gas common in the earth's atmosphere.
d) Hot - any temperature above 70 C

12. The teacher made a fancy pudding of layers as shown in the diagram

If this were a model of layers of rocks containing fossils, which would be the oldest fossils?

a) M & M's
b) Banana pieces
c) Cake
d) Peaches

13. Examine the diagram of a jar filled with water.



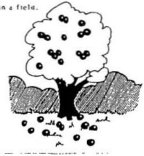
The volume of water is greatest in

a) section 1.
b) section 2.
c) section 3.
d) section 4.

14. Look at this picture of an apple tree in a field.

Just by looking at the picture, which one of the following statements can you be **most sure** is true?

a) The wind had knocked some apples off the tree.
b) There are apples on the ground and on the tree.
c) The apples on the tree are ready for picking.
d) The apples on the ground are spoiled.

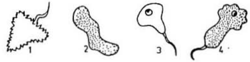


15. Look at the pictures of **imaginary** pond water animals

All of these animals are "jeds"

None of these is a "jed"

One of the animals in this row is a "jed".



Which one of the animals in the bottom row is a "jed"?

a) animal 1
b) animal 2
c) animal 3
d) animal 4

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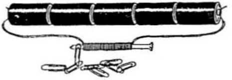
16. In experimenting with the effects of the number of batteries on the strength of an electromagnet, John discovered that when 5 batteries were placed in a circuit, as shown below, he could pick up 8 paper clips.



Before making any statement on the number of paper clips picked up by 5 batteries forming an electromagnet, the **best procedure** John could follow is to

a) do one more test and average his results.
b) do several more tests and average all the results.
c) report his first finding
d) report his last finding

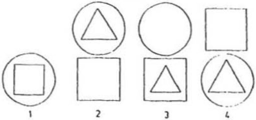
---

17. A class thought that younger people would remember more words than older people after studying a list of words for three minutes.

In testing this hypothesis, what variable would the class have to measure?

a) number of words to be learned
b) number of words remembered
c) the age of the people learning the words
d) the time allowed to learn the words

18. Barry drew a circle on his paper. Below the circle he drew a square inside the square he drew a triangle.



Which of these is Barry's drawing?

a) figure 1
b) figure 2
c) figure 3
d) figure 4

---

19. Powder is added to liquids 1, 2, and 3 as shown below.

Which inference is <u>best</u> supported by the above observations?

a) Liquids 1 and 3 are probably the same.
b) Liquids 1 and 2 are probably not the same.
c) Liquids 2 and 3 are probably not the same.
d) Liquids 1, 2, and 3 are probably all the same.

---

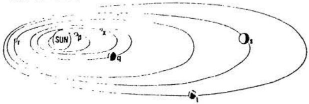
20. Sally tried a magnet on several things and made the following [illegible]

Name of Substance	Will Attract	Will Not Attract
Iron Nail	X	
Toothpick		X
Marble		X
Nickel Coin	X	
Silver Coin		X
Copper Wire		X

Choose the <u>most</u> logical conclusion Sally can make about [illegible] the table.

a) Magnets attract all metals and do not attract any non [illegible]
b) Magnets will attract wood
c) Magnets attract some metals but do not attract other [illegible]
d) Magnets will attract some glass items

21. This model represents the distances of some planets from the sun and shows their orbits



Which planet has an orbit around the sun which is longer than planet x's orbit but shorter than planet r's orbit?

a) planet s
b) planet q
c) planet t
d) planet p

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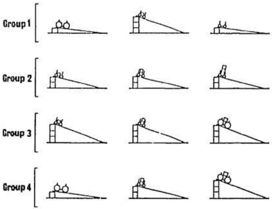
22. These diagrams show tests you can do with carts on slopes. They are all set up on the same kind of floor surface.



You want to test the hypothesis that "the heavier a cart is, the further it will travel away from the bottom of the ramp".

Which group of tests would you use?

a) group 1
b) group 2
c) group 3
d) group 4

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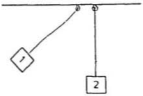
23. Two identical blocks are hanging by strings from a beam.



When block 1 swings down and hits block 2, block 2 will

a) not move at all.
b) swing to the left.
c) swing to the right.
d) bounce up towards the beam.

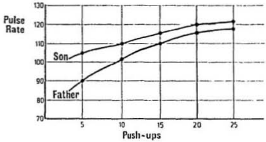
24. The operational (working) definition of the term "**weight**" is

a) the distance a spring is pulled down when an object is hung on it.
b) how big an object is.
c) the pull of the earth's gravity on an object.
d) a unit of measurement used to balance an object on a scale.

25. Which of these statements is a hypothesis?

a) This magnet picked up 12 paper clips.
b) The milk in this bottle froze in 20 minutes.
c) When a liquid is heated it expands.
d) The leaves on the birch tree have all turned yellow.

26. The graph below shows the change in pulse rate of a father and his son while they were doing 25 push-ups. Their pulse rates were measured for every five push-ups.



Which of the following statements is correct?

a) The son's pulse rate increased more than his father's pulse rate during the exercise.
b) The father's pulse rate increased more during the exercise than his son's pulse rate.
c) The son's pulse rate after 25 push-ups is twice his father's pulse rate.
d) The father and son have the same pulse rate at the end of the experiment.

APPENDIX B

1. <u>During the past school year 1991-1992, considering the time students spent on extra-curricular activities, what percentage of the allocated time for science did you actually teach science? (Please circle your answer)</u>

50% 60% 65% 70% 75% 80% 85% 90%

95% 100%

<u>I have used more than the allocated time to teach science.</u>

5% more 10% 15% 20% 30% >30%

2. <u>To how many different classes did you teach science? (Please circle your answer)</u>

   a) My own class only.

   b) My own class and another.

   c) My own class and two others.

3. <u>What percentage of the time, you have used to teach science do you estimate having spent on teaching about the complex processes of science (Formulating hypothesis; Defining operationally; Controlling variables; Interpreting data; Experimenting; and Formulating models) ? (Please circle your answer).</u>

<u>I estimate having spent ...</u>

0% 5% 10% 15% 20% 25% 30% 35% 40% 45%

50% 55% 60% 65% 70% 75% 80% 85% 90% 95%

100%

<u>of the time teaching about the complex processes of science.</u>

4. Of all the time you spent teaching about the processes of science, how would you break it down in terms of percentage spent on the different processes? (Please circle your answer)

Formulating Hypotheses

0 to 10% ; 10 - 20% ; 20 - 30% ; 30 - 40% ;

40 - 50%; > 50%

Defining Operationally

0 - 10% ; 10 - 20% ; 20 - 30% ; 30 - 40% ;

40 - 50% ; > 50%

Controlling Variables

0 - 10% ; 10 - 20% ; 20 - 30% ; 30 - 40% ;

40 - 50% ; > 50%

Interpreting Data

0 - 10% ; 10 - 20% ; 20 - 30% ; 30 - 40% ;

40 - 50% ; > 50%

Experimenting

0 - 10% ; 10 - 20% ; 20 - 30% ; 30 - 40% ;

40 - 50% ; > 50%

Formulating Models

0 - 10% ; 10 - 20% ; 20 - 30% ; 30 - 40% ;

40 - 50% ; > 50%

Please insert your answer sheet in the self-addressed envelope and return it to me by Tuesday, September 15. Thank you for your cooperation.

Sincerely yours,

Michel Genest
Graduate student
Faculty of Education
Memorial University of Newfoundland