ISBN 0-315-54812-6

THE EFFECT OF A HIGHLY INTERACTIVE COMPUTER SIMULATION ON STUDENTS' PROBLEM-SOLVING SKILLS

BY

CHERYL L. MCLEAN

A Thesis

Submitted to the Faculty of Graduate Studies

in Partial Fulfillment of the Requirements

for the Degree of

MASTER OF EDUCATION

Faculty of Education

University of Manitoba

Winnipeg, Manitoba

THE EFFECT OF A HIGHLY INTERACTIVE COMPUTER SIMULATION ON STUDENTS' PROBLEM-SOLVING SKILLS

BY

CHERYL L. McLEAN

A thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF EDUCATION

Abstract

Although problem-solving is a major focus in education many educators agree that schools frequently do not meet the goal of effectively teaching problem-solving skills. Computer simulations are an attractive solution to this problem offering problem- solving opportunities, realism, interactivity, and immediate feedback. There has been little research on simulations as a tool in teaching problem-solving, partly due to the lack of a suitable model of problem-solving and a lack of focus on simulations.

This case study was undertaken to identify the factors which may influence students' problem-solving skills in the context of a highly interactive computer simulation with database features. The subjects for this study were eight grade six students. Five topics appear to merit further attention, as they appear to be factors that had an influence on students' problem-solving skills in the context of a highly interactive computer simulation. The students' persistent use of guessing as a problem-solving technique provided some insight into their modes of problem-solving. The students' responses to this simulation suggest that providing challenges through some frustration may be an effective technique in designing simulations. Limited student frustration and the type of interaction present in cooperative learning appeared to be factors in the simulation that had an effect on students' problem-solving skills. In addition, the role of the teacher appeared to be a factor. All five factors suggested avenues for further research.

TABLE OF CONTENTS

Chapter 1 - Introduction

The Problem

Although problem-solving has long been the focus of attention for educators, many educators would point out that schools frequently do not meet the goal of effectively teaching problem-solving skills. (Chipman, 1985; Nickerson, Perkins & Smith, 1985; Polson and Jeffries, 1985; Moursund, 1988) Educators such as Ryba (1989) have suggested that computer simulations may be an effective tool to teach and apply problem-solving skills and therefore may contribute to the solution of this problem. While computer simulations are an attractive solution offering problem-solving opportunities, interactivity, realism, and immediate feedback, there has been little, if any, relevant research on the effect of highly interactive computer simulations on students' problem-solving skills.

A search of the literature reveals three properties of this problem.

1. No single model for problem-solving has as yet proved completely satisfactory.
2. Few studies have focussed on computer simulations as a means of teaching and applying problem-solving skills.
3. While it appears that the interaction between problem-solving and computer simulations may promote at least some problem-solving skills, it is not clear exactly what that interaction is or how it may be tapped to improve the quality of computer simulations.

One way to proceed with the study would be to wait for a complete and categorical model of problem-solving and apply that model to the design of computer simulations. Given the time-consuming nature of that approach a more practical and productive approach may be to study the entire phenomenon qualitatively with the hope of refining perceptions of the relationship between the two as a basis for future model clarification or empirical studies. The latter option has been chosen for this thesis. That, however, does not preclude the need to establish as precisely as is now possible the current state of research about problem-solving, computer-based simulations, and the relationship between the two.

Nickerson, Perkins, and Smith (1985) define problem-solving as "the behavior and thought processes directed toward the performance of some intellectually demanding task." (p.65) A similar definition from Chipman (1985) emphasizes the use of previously acquired knowledge and skill in this process. (p. 23) These are rather general definitions, so general that they cover almost everything. A more specific picture of problem-solving can be found by examining current problem-solving models.

Numerous models have been proposed in the attempt to conceptualize the nature of problem- solving. Some models emphasize the importance of domain-specific knowledge to the point of denying the existence of general problem-solving skills, others claim that problem-solving skills can be taught independent of content. (Polson and Jeffries, 1985) Sternberg's (1985) model describes a continuum from domain-specific to general skills. Polya's four stage model (1957) postulates the existence of problem-solving skills that are at least general to mathematics. Some of these models may be synonyms for one another or may be competing models. Others may be subsumed as part of larger models.

Polya's (1957) model suggests that the following protocol fits most problem-solving.

1. Definition of the problem
2. Selection of an hypothesis
3. Implementation of the hypothesis
4. Evaluation of the validity of the solution

The most secure way of looking at problem-solving at present seems to be to see it as a continuum from domain-specific problem-solving to general problem-solving with Polya's general protocol applied wherever possible.

A simulation is "an analogy of a real situation". (Flake, McClintock, and Turner, 1985, p. 265) The student is presented with a scenario that requires a decision or presents a problem. The student is required to analyze it and take some action, or make a decision based on the available information. The situation then changes according to the decisions made by the student, presenting the student with a new scenario. This process continues until the simulation is completed successfully, or the student makes enough incorrect decisions to end the simulation, runs out of time, or quits. (Lockard, Abrams, and Many, 1987, p. 155) Based on this definition it appears that simulations may actively engage students in problem-solving activities. In addition, computer simulations offer interactivity, realism, and immediate feedback which may be factors in promoting problem-solving skills.

While many studies have been published on the effectiveness of Logo or computerized databasing in teaching problem-solving, few studies have examined the effectiveness of computer-based simulations as a means of teaching and applying problem-solving skills. Part of the reason may be that for simulations to be analogous to real life they must be complex involving factors that are difficult to identify and isolate. Further, it is not always clear which problem-solving skills are being promoted nor is it clear how the interaction between the student and the simulation may promote these skills.

If problem-solving strategies for use in the context of computer simulations were defined simulations engaging these strategies could be designed. In addition, it is difficult to determine how these problem-solving skills, if that is what they are, should be applied to simulation exercises and what effect, if any, simulation exercises have on the development of these skills. This kind of case study may assist in sorting out the factors and determining the relationship between problem-solving and simulation exercises.

Therefore this is a case study of the relationship between a highly interactive computer simulation and students' problem-solving skills.

Objectives

The objective of the study is to identify factors which may influence students' problem-solving behaviour in the context of a highly interactive computer simulation with database features.

Two sets of cogent factors seem to be:

a) the things that happen in a simulation exercise,

b) things that may be unique to specific kinds of problem-solving or to particular steps in the problem-solving process.

Two other sets of factors seem to involve the interaction between the above two sets. They are:

c)the problem-solving strategies that are applied to the simulations,

d) the way simulation exercises may suggest channels or ways to solve problems.

The intent of this study, therefore, was to

i) learn about problem solving and the kinds of strategies students apply to simulations;

ii) infer things about simulation exercises with the goal of making them more effective problem-solving tools; and

iii) infer ways in which simulation exercises affect problem-solving skills.

Method

Data was collected in two ways:

1. Data was gathered in unstructured, model-free observations of the students while they performed the simulation. The following factors were observed:
   a. Students' response to the program,
   b. Students' response to the use of color in the program,
   c. Students recording of information for use in the simulation,
   d. Students' perceptions of the reasons for their success or failure in completing the program.

2. Four measurable factors were:
   a. Effects of a simulation on the impulsive/reflective behavior of students,
   b. Students' attention span,
   c. Students' use of the information database,
   d. Students' success rate in completing the program.

Chapter 2 - Review of the Literature

Introduction

> Of all creatures on earth, humans are the best at creating and solving problems. One of the main goals of education is to help students become even better at these endeavors. (Moursund, 1988, p.5)

Educators agree on the importance of teaching problem-solving skills in order to prepare students both to adapt to our world and to participate in modifying our society. Maintenance learning, according to Botkin et al. (1979), while indispensable, is not sufficient. Attention needs to be paid to how to better teach thinking skills. (p. 5)

It is commonly held that schools frequently do not meet that goal. (Chipman, 1985; Nickerson, Perkins & Smith, 1985; Polson and Jeffries, 1985; Moursund, 1988) Polson & Jeffries (1985) call attention to the lack of problem-solving skills shown by high school and university graduates. This lack is probably due to a number of factors, including a basic disagreement as to whether or not problem-solving can be taught as a general skill or is domain-specific, and a lack of empirical research on instructional methods that can improve students' problem-solving skills.

Many educators believe that computer simulations have the potential to be an effective tool in developing students' problem-solving skills.(Yates & Moursund, 1988; Tennyson & Thurlow, 1987; Ryba, 1988) Despite the proliferation of computer simulations, empirical research is limited and the most useful information comes from teachers' anecdotal reports. The lack of research may be due in part to the fact that as yet there is no suitable problem-solving model that defines the cogent variables.

I. Problem-solving

In this section, we examine the current research on problem-solving including, some models of human cognition that have influenced problem-solving models and some current problem-solving models. Major foci shaping these explorations include the role of domain-specific knowledge, metacognition, cooperative learning and cognitive styles.

That survey is followed by an examination of the research on computer simulations as a tool for teaching and applying problem-solving skills, focussing on the role of simulations in domain-specific knowledge, metacognition, cooperative learning, and cognitive styles.

Models of Human Cognition

Several majors areas in the study of cognitive psychology have influenced, and will continue to influence, the development of problem-solving models. One particularly thorny area is the definition of intelligence. The study of "intelligence" is very old, going back to at least Wundt and Binet. That literature is not reviewed here. More recent work on artificial intelligence has lead to a continuing re-definition of intelligence and new parameters as scientists attempt to create an intelligent machine. (Shank, 1984; Nickerson, Perkins & Smith, 1985) Memory is another grey area, with much recent attention being paid to the relationship between short and long-term memory. (Tennyson & Thurlow, 1987) A third area is the development of models of human cognition. Drawing heavily from the study of artificial intelligence, this area in particular has strongly influenced the development of problem-solving models. (Polson and Jeffries, 1985) A brief discussion of some of the current models of human cognition is appropriate.

Currently, the dominant theoretical paradigm in human cognition is the information processing model, but the competing divergent-production model has some adherents.

1. Information processing Model

This model, proposed in its present form by Newell and Simon, rests on two basic premises: 1) the human problem-solver is an information processing system and 2) problem solving can be characterized as both a search process and a process of what Polson and Jeffries call understanding.

The human information processing system, by analogy with a computer system, consists of inputs and outputs which interact directly with short term memory. (Polson and Jeffries, 1985) According to Tennyson and Thurlow (1987) working memory and long term memory are involved in this system. Short term memory and working memory both deal with immediate cognitive processes. Short term memory has a limited capacity and information is maintained for "the moment at hand (actually only a few seconds at maximum.)" (p. 153) Working memory involves "conscious effort or metacognitive awareness of the encoding process between itself and long-term memory." (p.153) Long-term memory contains both declarative information or factual knowledge and procedural knowledge or 'how to' knowledge. This is a serial system whose processes are executed in tens to hundreds of milliseconds.

Polson and Jeffries (1985) characterize problem solving in this system by the "interaction between the problem-solver and the task environment." (p. 419) Problem solving is seen as the intricate and complex interaction between the search process and the process of understanding. The understanding process generates a problem space which is the problem-solver's understanding of the givens, the goals, the possible solutions, and any problem-solving strategies that can be used. Each 'node' (which is not defined by Polson and Jeffries) represents a possible state of knowledge. The search processes are characterized as transitions between knowledge states. Search processes can add new information, therefore changing the understanding processes which in turn lead to changes in the problem space thus generating new search processes. In this model emphasis is placed on the importance of domain-specific knowledge for problem-solving. (p. 418-419)

This is a model based on theory rather than production and much of the research in this area is based on modelling human cognition and programming computers to perform problem-solving tasks. (Nickerson, Perkins & Smith, 1985, p.70)

2. Divergent-production Model

According to Polson and Jeffries (1985), this model subsumes most recent work not based on the information processing model. The emphasis is on the production of programs of instruction to enhance what they call creativity in educational and other applied settings and to improve thinking and problem-solving across the full range of instruction. Creativity is not defined.

In this model, problem-solving is seen to be a general skill that can be taught. (p. 426) Often the general strategies are developed by inference from observations of experts' problem-solving. (Nickerson, Perkins & Smith, 1985, p.70)

Shank's (1984) categories of the 'theory-directed' approach and the 'product directed' approach to artificial intelligence are similar to the information processing model and the divergent production model. His theory-directed approach focusses on using computers to model what he calls human cognition. Human cognition is seen as an information processing system. On the other hand, his product directed approach often examines expert behavior in problem- solving with the goal of producing a useful computer product, such as a medical diagnosis program or a program to play chess.

Problem-solving Models

Polson and Jeffries (1985) describe three general problem-solving models but point out that there is insufficient evidence to warrant choosing one over the other.

Model I assumes that problem-solving skills are general skills that can be taught independent of content. A program based on the information-processing framework and following this model would focus on search techniques, understanding heuristics, and controls to integrate these techniques into a coherent body of problem-solving knowledge that can be applied to specific content areas.

Model II requires domain-specific knowledge as its base but acknowledges that general skills do exist that can be abstracted by the student from repeated work in solving problems in specific domains.

Model III maintains that there is no such thing as general problem-solving skills. Any skills developed are directly related to domain-specific knowledge. Studies of expert problem-solving have suggested that knowledge and problem-solving techniques are so closely interwoven that they cannot be separated.

Sternberg's (1985) model of problem solving appears to be based on the information-processing model. He describes the three kinds of mental processes:

> 1) metacomponents, or the executive processes used to plan, monitor, and evaluate problem solving; 2) performance components, or the non-executive processes used to carry out the instructions of the metacomponents, and 3) knowledge-acquisition components, or the non executive processes used to learn how to solve the problems that are then controlled by the metacomponents and solved by the performance components. (p. 278)

Sternberg makes a clear distinction between problem-solving as it is often taught in schools and adult problem-solving. He presents ten characteristics of real-life problem solving that rarely occur in school problem-solving programs. They include:

1. the importance in recognizing that a problem exists
2. the difficulty in figuring out exactly what the problem is
3. the ill-structured nature of everyday problems
4. the difficulty in finding the necessary information to solve the problem
5. the interaction of the problem with the context in which it is presented
6. the frequent lack of no one right solution or even criteria for the best solution
7. the dependence of the solution on informal knowledge as well as formal knowledge
8. the consequences of real-life problems that really matter

9. the fact that people often have to work as groups to solve problems
10. the messy, complicated, and persistent nature of real-life problems

His model looks at problem-solving as a continuum from domain-specific knowledge to general problem solving skills. He emphases sampling a variety of content domains and a variety of thinking skills keeping the problem characteristics as close to real-life as possible.

Polya's (1957) model, which is the basis of a variety of other models, assumes the existence of general problem-solving skills. If pressed, Polya might have agreed that his steps are domain specific to mathematics, but he did not so restrict them in his discussion and numerous later interpreters have supposed that they have other applications. His general list includes:

1. Definition of the problem
2. Selection of an hypothesis
3. Implementation of the hypothesis
4. Evaluation of the validity of the solution

Other educators have developed models derived from Polya's. (Ryba, 1988; Scardamalia, Bereiter, & McLean, 1988) Moursund's (1988) model, for example, contains givens, guidelines, goals, and ownership. Givens are what is known about the problem, guidelines are the rules or steps used to reach the goal, the goal is the desired result, and ownership is the personal investment that the problem-solver has in the problem. (p.13)

Heuristics

Most models contain heuristics, "methods, principles, and rules of thumb that work reasonably well in many instances...[They] are not guaranteed to work but often do." (Nickerson, Perkins & Smith, 1985, p.74) Again, many of these procedures are based on Polya's work. Some examples of heuristics are:

- In order to solve a problem, make sure you understand what it is you are asked to solve. Have a clear understanding of the information that has been given and the possible operations that may be performed in order to reach a solution.

- An effective way of dealing with a large problem is to break it up into smaller, more manageable, parts and solve them before attempting the larger problem.

- If you are asked to provide a solution to a problem whose goal state is known it is often effective to work backwards from the goal state to the initial state.

(Nickerson, Perkins & Smith, 1985, p.74)

It is clear from the above discussion that no one model has been accepted as the definitive model of problem-solving. For the purposes of this paper, it seems best to look at problem-solving as a continuum from domain-specific skills to general skills with Polya's protocol being used at various levels along the continuum.

Major Foci

Domain-specific vs General Problem-solving Skills

As indicated previously, one of the major foci in this field concerns the role of domain-specific knowledge in problem-solving. Chipman (1985) and Glaser (1985) point out that recent research in knowledge-rich domains has frequently shown that cognitive skills appear to be extremely content specific. Expert performances seem to be based on vast amounts of knowledge rather than on general problem-solving skills. They do not deny the existence of strategies to manipulate this knowledge but hold that they are irrevocably linked to the knowledge itself. Polson and Jeffries support this view by reporting that problem-solvers often fail to transfer general problem-solving skills to other content areas. (p.450)

Still, the similarity of heuristics such as means-end analysis within different domains remains compelling, suggesting that the teaching of generalized problem-solving skills ought to be possible, and program developers continue to emphasize skills and motives at a general level.(Greeno 1985, pp. 210-211) Belmont, Butterfield & Ferreti (1982) (cited Ryba, 1989) have shown that self-management strategies when specifically taught are more likely to transfer to new learning situations, suggesting that general skills can be taught.

Simon (1980), while stressing the importance of knowledge in problem-solving, claims:

> The evidence from close examination of AI (Artificial Intelligence) programs that perform professional-level tasks, and the psychological evidence from human transfer experiments, indicate both that powerful general methods do exist, and that they can be taught in such a way that they can be used in new domains where they are relevant. (p. 86)

Many of the authors examined shared the view that general skills and domain-specific knowledge are both important components of problem-solving. (Greeno, 1985; Nickerson et al., 1985; Chipman, 1985; Glaser, 1985; Simon, 1980) Glaser (1985) states and I concur that:

> Perhaps both generalizable and specific levels of thinking could be taught in the course of acquiring subject-matter knowledge and skill - particularly in interactive instructional situations, where there is emphasis on active inquiry as learning occurs. (p. 615)

Metacognition

One of the candidates for a general problem-solving skill is 'metacognition'. Brown (1985) defines metacognition as "the cognitive activities of self-reflection, self-monitoring, and revision in learning." (p.112) Some examples of self-monitoring or metacognitive strategies include: goal setting, strategic planning, self evaluation and revision strategies. (Ryba 1989 p.1) Other examples, as described by Gagné (1985) and reflecting Polya's influence, include understanding of the task goal, knowledge of appropriate learning strategies, selection of appropriate strategies, and self-monitoring.

According to Ryba (1989), the ultimate aim of education is for learners to become independent thinkers and problem-solvers, and this depends on or is enhanced by the ability of students to reflect on their own thinking. (p.2) Effective metacognitive strategies characterize successful lifelong learners. (Brown, 1985, p.108) Such learners are found to " use a variety of cognitive strategies and self-management procedures to pursue knowledge related goals, to relate new knowledge to old, to monitor their understanding, to infer unstated information, and to review, reorganize, and reconsider their knowledge." (Scardamalia et al., 1987, p.6) Gagné and Glaser (1987) agree and point out that in addition to being deficient in the knowledge required to solve problems, unsuccessful learners are often weak in self-regulatory skills. This weakness generally shows up in more difficult problems in which these learners do not adjust as flexibly as successful learners and do not see a problem through to the end. (p.77)

Cooperative Learning

It is generally agreed that metacognitive skills may be facilitated through cooperative or collaborative learning. (Brown, 1985; Webb, 1987; Cosden and Lieber, 1986). As cooperative learners, students tutor each other, explain their reasoning behind problem solutions, share their knowledge and expertise, or play particular roles in learning experiences. (Brown, 1985, pp.109-110) Students thus shape their own problem-solving behaviors by observing the behavior of others. Cooperative learning abandons significant interest in the mechanisms of problem-solving and it assumes that they are 'in there'. The focus is on engaging them, whatever they are. Cooperative learning is therefore not a competing model of problem-solving; it is a proposed mechanism for making it work.

Cognitive Style

Baron (1985) suggests that thinking skills may interact with cognitive style. Cognitive styles are "general behavioral dispositions that characterize performance in mental tasks; they are intellectual personality traits. Examples are reflection-impulsivity and sensitivity to evidence against one's favored beliefs." (p. 366)

In addition to Baron, a number of authors (Messick, 1976; Mussen, Conger & Kagan, 1979; Kagan, 1984) have emphasized the importance of reflection-impulsivity on students' thinking skills. Messick (1976) describes reflectivity vs impulsivity as a cognitive style specifically involving "individual consistencies in the speed and adequacy with which alternative hypotheses are formulated and information processed..." Impulsive individuals are seen as those who offer the first solution or answer that occurs to them although it is frequently incorrect, while reflective individuals consider a number of possibilities and reject poor hypotheses before offering a solution. (p. 19) Kagan (1984) further refines the definition, stating that this style is only applicable to those problem solving situations where the child believes an aspect of his intellectual competence is being evaluated. The child holds a standard for quality of performance on the task, understands the problem, and believes he knows how to achieve a solution. Several equally reasonable response alternatives must be available, but the correct answer should not be immediately obvious. (p. 228)

Kagan sees reflectivity/impulsivity as a quality of evaluation - the fourth process in problem-solving. He says evaluation "pertains to the degree to which the child pauses to consider and assess the quality of his or her thinking. This process influences the entire spectrum of mental work: initial perception, recall and hypothesis generation." (p. 270)

It seems to be generally held that, in our society, reflectivity is a desirable trait. Kagan reveals that bias when he suggests that impulsive students can be trained to be more reflective.

To summarize the literature, instruction in effective problem-solving would likely entail: (1) general and domain-specific guidance in problem-solving (2) metacognitive strategies (3) strategies for cooperative learning (4) training in reflectivity as a cognitive style.

II. The Technology

Instructional Technology

The field of instructional technology is concerned with the development and use of instructional techniques to promote effective human learning. One goal for research and development in this field is to be able to specify the "characteristics of a system of media that would make possible a set of conditions for optimally effective learning that would exceed the capabilities of instructor-mediated instruction." (Gagné, 1987, p.6) Gagné points out that modern communications and computer equipment and discoveries in human cognition provide good prospects for the development of a such a media system.

Instructional technology draws upon knowledge and expertise from disciplines such as cognitive psychology and its investigation of human learning and the conditions of instruction. The investigations of human problem-solving, as described in the previous section, provide an example of the type of research that could provide direction for developers of computer software aimed at teaching problem-solving. Rapid changes in the technology and capabilities of hardware systems, particularly microcomputer systems, constantly suggest new modes of instruction. (Gagné,1 1987) For example, systems are currently being developed that will allow natural language queries and modelling of a student's knowledge state. (Williams, McLean & Bochonko, 1986) At the most speculative level, cognitive psychologists are attempting to use computer systems to model human cognitive behavior as a way of possibly understanding human cognition.

Instructional technology is also concerned with the effect of microcomputer systems delivering instruction at a practical level. (Gagné, 1987, pp. 6-7) Much of the literature deals with studies of computer assisted instruction.

Computer Assisted Instruction

Wright and Forcier (1985) define computer assisted instruction as "a learning environment characterized by instructional interaction between computer and student." The teacher sets up the learning environment and ensures that each student has the appropriate precursor skills with which to interact in this environment. (p. 96) At its best, computer assisted instruction combines the knowledge gained by the cognitive psychologists with the unique instructional capabilities of the computer. Computer assisted instruction is now a major vehicle of instructional technology. It can take a variety of forms including drill and practice, tutorials, games, and simulations.

Simulations

Simulations are "an analogy of a real situation" (Flake, McClintock & Turner, 1985, p.265) the purpose of which is to assist the student in building a useful mental model of part of the world. The opportunity is provided to test the model safely and efficiently by performing the required tasks or making the required decisions. (Alessi & Trollip, 1985, p. 161)

Alessi and Trollip (1985) describe four types of simulations:

1. **Physical**

   In this type of simulation, the student learns about or uses some physical object. Examples include flight simulators, which have been successfully used in training pilots, and science laboratory simulations, in which students are required to perform distillation experiments.

2. **Procedural**

   The student learns a series of steps or sequence of actions relating to a specific procedure. Examples include operating a telephone or performing a titration. Many physical simulations must have procedural components because a procedure often must be learned in order to use a physical object.

3. Process

In this type, the student sets the parameters for the simulation at the beginning. Then the computer completes the simulation without further intervention by the student. An example is economic forecasting.

4. Situational

The student takes the role of a character in a scenario and must make decisions based on the available information. Appropriate decisions generally lead to a successful outcome. Inappropriate decisions lead to a worsening of the situation and eventual failure if enough inappropriate decisions are made. Situational simulations are unique in that they often deal with attitudes and behaviors of people rather than skilled performance. A simulation emulating the first year of teaching is an example. (pp. 162-172) This description assumes a convergent plan on the part of the author. Simulations need not be convergent. They can be designed to produce multiple outcomes such as in the "choose your own adventure" stories currently popular with children.

Alessi and Trollip's categories may not be particularly useful. It seems that many simulations could fall into several or all of their categories, suggesting a flawed set of categories. Any simulation can be seen as containing elements of several or all of the above. For example, in John Rae I - The Journey Begins (MCALC, 1988) the student takes the role of the 19th century master arctic explorer, John Rae. The simulation could be considered to be primarily situational as Rae must deal with the attitudes and behaviors of both the explorers and native people of his time. But the student must also display procedural skills, such locating the intersection of latitude and longitude lines in order to establish his/her position on a map. Elements of process simulations are also present, as students must choose supplies at the beginning of the simulation and then wait to see if they have enough to complete the journey.

In what follows we will use the above categories to identify the components of simulations without supposing that they lead to any clear partitions between simulations.

Computer Simulations and Problem-Solving Skills

Computer simulations, and situational simulations in particular, appear to have as part of their structure the elements of problem-solving proposed by Polya (1957):

1. Definition of the problem
2. Selection of an hypothesis
3. Implementation of the hypothesis
4. Evaluation of the validity of the solution

They are thus likely candidates for teaching those problem-solving skills. The student is faced with a situation requiring a decision. S/he must examine the problem and select an hypothesis. Once a decision has been implemented, feedback is provided, allowing the student to evaluate his/her performance. In addition, simulations have the potential to be effective in the areas of major concern for problem-solving including: domain-specific and general problem-solving skills, metacognition, cooperative learning, and cognitive style.

Domain-specific Skills and General Problem-solving Skills

The particular problem skills being taught can be either domain-specific or general, depending on the simulation. Some simulation software reflects a specific domain and requires unique strategies resulting in detailed problem-solving in that domain. (Norton & Resta, 1986, p. 36) It is also speculated that general problem-solving skills can be taught effectively. The presence of strong similarities between simulations and real-life may enhance the possibilities of the transfer of skills to other domains. (Alessi & Trollip, 1985, p.172) A major concern, however, is the accuracy of the content. Due to the complexity of simulations it is difficult to assess the realism of the scenario and the validity of the underlying model. (Lockard, Abrams & Many, 1987, p. 158)

Metacognition

As discussed in the previous section, metacognition can be thought of as a general problem-solving skill. According to Ryba (1989), computers may help to build what he calls "environments for thinking". He refers to the development of these environments as the ecological approach. (1988) Through their interactive and motivating methods such environments are intended to encourage students to examine their thinking processes. (Ryba, 1989; Lockard, Abrams & Many, 1987)

The interactive and motivating nature of simulations that involve immediate feedback on decisions may contribute to the development of a rich ecological learning environment and may encourage students to examine and improve their problem-solving skills. (Lockard, Abrams & Many, 1987, p. 158) The teacher may also play an important role in the development of this environment by modelling, promoting, and actively teaching effective problem-solving skills. (Ryba, 1989; Pogrow, 1987)

Numbers of contributors to this field have been attracted to what are called 'microworlds' as a way of probably enhancing the ecological approach and encouraging students to examine their own thinking. Seymour Papert defines a microworld as

> a subset of reality...whose structure provides an environment where learner's cognitive mechanisms can operate effectively. The concept leads to the project of inventing microworlds so structured as to allow a human learner to exercise particular powerful ideas or intellectual skills.
> (Papert, 1980)

Although Papert was referring to the computer language/environment Logo, simulations in general can be subsumed under the notion of microworlds. By definition, they are a subset of reality. The rules are simplified and limited, encouraging students to focus on particular aspects of reality and concentrate on the most relevant skills. (Alessi & Trollip, 1985, p.172)

The relationship between a microworld and the ecological approach to learning is subtle. Generally, the ecological approach refers to the child's total learning environment - his/her classroom, other students and his/her relationship to them, the teacher, and the activities in which the child engages. The teacher's goal is to draw all of these factors together in order to create an environment for thinking. Microworlds also provide a learning environment for thinking, but they are generally limited to the computer program or language with which the child is working. A microworld such as John Rae I - The Journey Begins would be part of the child's learning environment in the ecological approach, but would not be the entire environment.

Cooperative Learning

Early critics of microcomputers feared that computers would isolate students and prevent cooperative learning. (Bracey, 1982) Webb (1987) points out that this has not happened, partly due to the push by both teachers and students for peer interaction and collaboration. The scarcity of hardware and the public nature of the microcomputer screen may also have helped vitiate that danger. The microcomputer screen is more public than paper and pencil; students can more readily learn from each other by seeing how others solve problems. (Cosden & Lieber, 1986, p.167)

It is speculated that simulations may be a useful vehicle to promote cooperative learning as a means of improving thinking skills. Students working together to make decisions may be modelling their skills by having to defend or explain the reason for a decision. The act of explanation may enhance students' thinking about their own thinking. In addition students are provided with the opportunity to observe others' problem-solving skills.

Webb (1987) has reviewed a number of studies of peer interaction on microcomputers. No study reported significantly greater learning when students worked alone than when they worked in groups. Five studies reported greater learning in groups and nine studies reported no difference. Encouraging results were obtained on on-task interaction and helping behavior. Most of the interaction consisted of making specific suggestions about the task, such as what to type on the keyboard and how to change a line of code. Students rarely discussed the purpose of their tasks in drill and practice programs or the planning of activities in Logo. Most discussions focussed on accomplishing the task. Simulations are not mentioned in this review. Most of the studies examined Logo or drill and practice programs.

Cognitive Style

Simulations may provide a vehicle for training students to be more reflective in their behavior. As required by Kagan's model, simulation decisions generally entail several reasonable-looking options. In good simulations the answer is not immediately obvious. Whether or not the student believes his intellectual competence is being tested will depend on the importance the student places on completing the simulation successfully.

In the simulation John Rae I - The Journey Begins, an attempt is made to reinforce reflective behavior by providing rewards for students who examine all available evidence before making a decision. Students who make rash decisions without examining the evidence could find the situation deteriorating. Direct instruction on examining all available evidence is intended to assist students to develop reflectivity in their thinking.

Summary

"Critics note that when using simulation programs, it is often difficult to assess just what has been truly learned." (Lockard, Abrams & Many, 1987, p. 158) This may be due in part to the complexity of and the scarcity of research on simulations and the other reasons identified earlier, such as the lack of an appropriate problem-solving model.

Research on the effect of simulations on students' problem solving skills is limited. (Woodward, Carnine & Gersten, 1988) Most computer assisted instruction studies dealing with thinking skills or problem-solving, have focussed on Logo (Webb, 1987, Ryba, 1988, Ryba, 1989) or tool applications such as databasing, wordprocessing and spreadsheets. (Scardamalia, Bereiter & McLean, 1988) Many have dealt with learning disabled students rather than the general student population. (Mineo & Cavalier, 1985; Ryba, 1988, Cosden and Lieber, 1986) The most useful information comes from teachers' anecdotal reports. (Eiser, 1986; Pogrow, 1987)

Two studies have focussed on simulations and their effects on students' problem-solving skills, with encouraging results.

Norton and Resta (1986) examined simulations, problem-solving software, and integrated learning systems for their impact on elementary students' reading achievement. The Purdue Elementary Problem-Solving Inventory developed by Feldhusen was used as a test instrument. The results indicated that the students profited more from instruction supplemented by problem-solving and simulation software than from traditional methods. No models for problem-solving were proposed and the variables from the simulations that may have affected this outcome were not examined.

The HOTS (Higher Order Thinking Skills) program described by Pogrow (1987) used simulations and other computer software to develop students' higher order thinking skills. The program's goal is

> to help students internalize the basic thinking processes that underlie all learning and to break the remediation cycle. Students learn how to apply information and how to generalize and talk about ideas in ways that demonstrate they have the thinking skills necessary to learn content the first time it is taught in the classroom and be able to apply it to problem-solving situations.

Pogrow states that it takes almost two years of daily classroom work with constant questioning and dialogue between teacher and student before the students use their new higher order thinking skills automatically. Although the measurements used for thinking and social skills are not mentioned, he does report gains exceeding 15 percentile points on standardized reading tests the first year.

Pogrow's program focuses on the HOTS curriculum, the drama and questioning techniques used by the teacher, and direct instruction of content in the regular classroom. The HOTS curriculum consists of daily lessons (using popular commercial software such as Oregon Trail, a simulation from MECC) that are intended to develop metacognition, inference, decontexualization, and combining and synthesizing information. He points out that, as the program revolves around the drama and questioning techniques used by the teacher, the software can be relatively simple, but must be highly motivating. An example is the program SNAP (based on the children's card game) by the Lawrence Hall of Science. It is a simple game designed to develop word matching skills. The teacher involves students in making predictions and generalizations about the meaning of the concepts "SNAP" and "Reaction". Other than being highly motivating, no other qualities of the software that are intended to produce these results are identified explicitly.

III. Purpose and Rationale

From the literature review, it not clear what aspects of either the computer simulation, or the learning environment, have an effect on students' problem-solving skills; nor is it clear how students' problem-solving skills are applied to simulation exercises. The studies reported by Pogrow (1987) and Norton and Resta (1986) and an examination of the literature on problem-solving and computer simulations suggest that computer simulations have the potential to be an effective tool in developing students' problem-solving skills. It is apparent that, as yet, there is no appropriate model from which to extract and test the cogent variables. It is speculated that the qualities of the simulation itself, the qualities of the learning environment, and the interaction between the simulation and students' problem-solving skills will be factors.

This case study was undertaken to examine and observe student behaviour when working with well-designed simulation software. The purpose of the study is hopefully to detect variables in the interaction between a simulation and students that may lead to more refined models for later study.

Chapter 3 - The Method

I. Description of Subjects

The subjects for this case study were eight sixth-grade students from one classroom - four males (two twelve year olds and two eleven year olds) and four females (one twelve year old and three eleven year olds). All were successfully completing the final month of grade six.

The school, with a student population of approximately 476 students, is located in a predominantly average to upper middle class neighborhood. The two grade six classrooms are grouped heterogeneously with approximately 27 students in each room. There is a central computer lab containing 14 Apple IIe computers and several Commodore PET computers. There is a division computer consultant, but no school computer specialist.

The teacher has used computers in his classroom frequently for computer assisted instruction, computer literacy, and wordprocessing.

The students were experienced in and comfortable with loading and running computer assisted instruction programs independently. While the students were not familiar with John Rae, the protagonist in the software being tested, they had studied other explorers of this era and were familiar with terms such as 'pemmican'. Although most students recognized the terms 'latitude' and 'longitude', the group as a whole requested a brief review on locating specific points using latitudes and longitudes given in degrees and minutes.

The participating students were selected by the teacher so as to sample the range of abilities in his classroom. This small sample was not intended to be representative of any particularly identified population as would be required in an empirical study. The intent of this case study was to detect possible novel variables in the interaction between an interactive computer simulation and problem-solving. For that purpose, having as broad a range of participating students as possible is the most cogent factor.

Permission for the study was obtained from the school division, the school principal, the teacher, the parents, and the students.

II. Research Design and Procedures

A. Type of Study

This was a case study for the purpose of model building. The intent was to identify the most cogent variables present when students use a highly interactive computer simulation with a database feature as a means of improving problem-solving skills. It may be viewed as an attempt to detect significant factors in simulations and the learning environment as well as the problem-solving skills students apply to simulations. Data was gathered through measurement, observation, and surveys with the hope of triangulating inferences.

A pilot study was conducted with two grade six children from another school in the same area.

B. Collecting the Data

Step 1 - Initial Group Meeting

The researcher first met with all eight students as a group. Introductions were performed and each student was assigned a number between 1 and 8 alternating males and females. The computers and disks were also numbered. The procedures to be followed were explained. The students were told that the purpose of the study was to test a piece of computer software.

Step 2 - The Matching Familiar Figures Pretest

The researcher met with each student individually. Name, age, and birthdate were recorded. The Matching Familiar Figures Test which is described later was administered.

Step 3 - Introduction to the Simulation

The researcher again met with the group as a whole. The explorer John Rae was introduced. The students were told that the objective of the computer simulation was to travel successfully by open boat from Churchill to Repulse Bay on the shore of Hudson Bay. Pertinent places were pointed out on a map. A brief (5-10 minute) review of latitude and longitude in degrees and minutes was carried out. The students were each assigned to a computer, alternating males and females.

Each student was provided with a computer disk containing the simulation, a data disk on which to save his/her work, and a notebook on which to keep any notes that s/he felt were relevant.

Additional books and materials on northern explorers were displayed on a table near the computers. The students were told that if they wished to take breaks from the program they could examine these materials.

The students worked on the simulation for a maximum of seventy-seven minutes in the morning followed by the lunch break. Students were permitted to work on the program in the afternoon until all had completed the program at least once.

Step 4 - Observations

The researcher acted as a participant as well as an observer, answering questions when requested.

The following measurable results were recorded:

1. The length of time each student spent working on the program and the length of time spent working with alternate materials

2. The number of attempts and the time required to complete the program successfully
3. The degree of success in the program as measured by the number of days required to reach the goal

In addition, the number of times each student accessed specific portions of the information database was recorded on each student's disk. The program was adjusted to record the number of times the student accessed the database. Unfortunately, this data was obtained for only four students. Three possibilities could account for the lack of data on four disks: the students did not access the database at all, the students accessed the database the first time through the program, but not the second time, and the data from the first attempt was erased, or the disk or the programming was faulty. It is impossible to be sure which of the above is correct.

The following were observed and recorded in less formal ways:

1. Comments made by students
2. Questions asked by students either of the researcher or other students
3. The parts of the program the student accessed to solve problems

Step 5 - Matching Familiar Figures Posttest

The Matching Familiar Figures test was again administered individually. Five students were tested immediately and three the following morning. It was clear that most students remembered their answers from the pretest, rendering the results suspect.

Step 6 - Interview or Survey

The researcher interviewed each child. Again five were interviewed immediately and three the following morning.

All data was collected over a period of 1.25 school days.

C. Computer Program

The computer program chosen, John Rae I - The Journey Begins, is a situational simulation based on the 19th century Arctic explorer, John Rae. In this program Rae and twelve companions must travel by open boat from Churchill to Repulse Bay where a base camp is to be built. The student must choose appropriate supplies, recognize his/her position on the map using latitude and longitude, make appropriate decisions about travelling under variable weather conditions on Hudson Bay, and complete a wildlife report. The wildlife report is based on the animals seen during the journey and uses a modified cloze technique.

The program has an extensive database accessible through most screens and includes current weather conditions, advice, a map, elapsed time, a glossary, a supply list, and a wildlife list. Its purpose is to encourage students to find out all pertinent information before making a decision.

The program had been field tested in Manitoba schools with good results.

The program was developed by the Manitoba Computer Assisted Learning Consortium and permission was obtained for its use in this study.

III. Description of Measures Employed

The Matching Familiar Figures Test

The Matching Familiar Figures test, by Jerome Kagan, (elementary version) is a visual recognition task used to establish the student's tendency to be either impulsive or reflective, and is regarded as the primary index of reflexivity-impulsivity.

The student is shown a single picture of a familiar object and six variants of this object only one of which exactly matches the original. The student is asked to select the one object that matches exactly. The researcher records the time until the first response to the half-second, the total number of errors for each item, and the order in which the errors are made. Students are allowed a maximum of six errors. The test contains twelve exercises, the first two of which are practice items. See Appendix A for sample items from the test.

The critical variables are the time to the first response and the the number of errors in the test. These two variables are generally considered to be the two dimensions found in reflectivity and impulsivity. (Kagan, 1984)

The test is scored in the following manner. The mean response time across the twelve initial responses is calculated. The mean of the total number of errors is calculated across the twelve items. Kagan provides sample mediums with his test. Fast times are means under seven or eight seconds; slow response times are means greater than twelve seconds. Accurate responses are means less than two errors; inaccurate responses are means greater than two errors. Traditionally there are four categories into which students may fall when scoring the Matching Familiar Figures Test, all based on Kagan's sample mediums.

1. Reflective or slow/accurate - these students fall below the sample medium for errors (<2) and above the sample medium for time (>12 seconds).
2. Impulsive or fast/inaccurate - these students fall above the sample medium for errors (>2) and below the sample medium for time (<7 or 8).
3. Slow/inaccurate - these students are not classified as either impulsive or reflective. Their score fall above the sample medium for errors and above the sample medium for time.
4. Fast/accurate - these students are not classified as either impulsive or reflective. Their scores fall below the sample medium for errors and below the sample medium for time.

There is no information available on the reliability or validity of this test. Permission was obtained from Jerome Kagan to use it.

Student Notebooks

The students were encouraged to use notebooks in which they could record notes as they wished. Each notebook included a place to record the supplies chosen for the journey, a map on which to record the locations found on the journey and the dates, and several diary pages on which to record observations.

Students had two of major problems to solve - choosing supplies and recognizing places using latitude and longitude. The purpose of the diary pages was to focus students on the value of written notes in situational problem-solving. See Appendix A for a sample of the notebook.

Observation Recording Sheet - Student Record

Separate sheets were used to record observations of students. The first section was used to record the time spent on the program and the time spent on additional print materials. In the second section, records were kept on the student success rate, including the attempt number, the time, the event at which the program ended, and the student's comments. The third section was reserved for general observations including student comments and questions. See Appendix A for a sample of a student record.

Interview Sheet

Each student was asked the following questions. The answers were recorded by the researcher on individual sheets.

1. Did you like the program? Why or why not?
2. What part(s) of the program did you like the best? Why?
3. What part(s) of the program did you like the least? Why?
4. Did you reach Repulse Bay successfully? Why or why not?
5. If you had a chance to do this program again, what would you do differently?
6. Did you have a colour monitor? Would having or not having a colour monitor for this program make a difference to you? Why or why not?
7. What was difficult about the program? Why?
8. What did you do about the difficult part(s)?
9. What was impossible? Why?
10. What was challenging? Why?
11. What was the easiest part of the program? Why?
12. Did you use the database? Was it helpful? Tell when you used it.
13. What do you think you were supposed to learn from this program? Did it work?
14. Suppose you were travelling to a place called Okura with your family for a holiday. You are in charge of making the family clothing list. How would you decide what clothing to take?

The purposes of the interview were:

1. To discover what (if anything) the child found motivating about the program
2. To discover what heuristics the student believed s/he used in solving the problems
3. To discover what the student thought about his/her own thinking skills
4. To discover whether or not the general thinking skill of finding out all pertinent information about a problem before attempting a solution might transfer to other areas

Chapter 4 - Results

The measurable results and observations from this study will be discussed within each of the four major contemporary views of problem-solving: domain-specific and general problem-solving skills, metacognition, cognitive style, and cooperative learning.

I. Domain-specific and General Problem-solving Skills

The program was designed to promote several general problem-solving heuristics. The two most significant were:

1. When presented with a problem ensure that you understand the question and all the terms used.

2. When presented with a problem look for and examine all information available on possible solutions before proceeding.

The technique used in the simulation was to provide an information database containing information necessary for making decisions.

The following table indicates the number of times the student accessed the database. Information is not available for four students. As pointed out previously this may be due to difficulties with the record keeping portion of the program. Four disks contained no records of database access, yet observations and comments made by the students indicated that at least three of the four students in question did use the database suggesting that the problem lies with the programming.

TABLE 1

Student	Weather	Temper-ature	Advice	Time	Map	Glossary	Food Supplies	Other Supplies	Wildlife
1	no record								
2	6	3	7	2	7	4	1	1	5
3	no record								
4	1	1	2	2	2	1	3	0	4
5	no record								
6	no record								
7	0	2	8	1	6	2	2	0	1
8	9	3	2	1	0	1	0	0	0
Totals	16	9	19	6	15	8	6	1	10

Three areas in the program appeared to provide the students with the most opportunities to practice or develop their problem-solving skills.

1. Choosing Supplies

Near the beginning of the program the students were required to choose appropriate food/fuel supplies and other supplies for the journey.

A. Food and Fuel Supplies

The food and fuel supplies were divided into two sections - those supplies measured in kilograms and those measured in litres. The students used the cursor controls to either increase or decrease the amounts of each item taken. As the student moved from item to item the way in which each item was measured was indicated at the bottom of the screen. For example, pemmican was measured in 40 kg bags. If the student chose to take 10 bags of pemmican the total weight of the pemmican was calculated automatically at 400 kg. Pemmican, grease, flour, tea, sugar, and chocolate were all measured in kilograms. A maximum weight for all of these items combined was given. The student was not permitted to exceed this maximum. Fuel alcohol and brandy/wine were measured in litres. Again a maximum volume was given which students were not permitted to exceed. The students were to decide on the amounts of each item to take without exceeding the allowed limits - a difficult problem without some assistance.

Assistance was provided in two ways.

1. One item on the food and fuel list was `GET HELP'. Choosing this item accessed a menu that included a glossary and advice. Advice was available from two advisors; the chief factor at Fort Churchill who provided very specific advice and a gentleman explorer whose advice was irrelevant. The chief factor's advice was:

> You have enough room to take meat supplies (pemmican) for 4 months. You can expect the men to eat about 160 kg or 4 bags per month.
>
> Your flour, tea, sugar, and chocolate, however, will have to last the entire year. You will likely use 2 bags of flour per month and a little under a bag each of sugar, tea, and chocolate.
>
> A little grease goes a long way.

The gentleman explorer's advice was:

> Don't expect to live off the land.
>
> You must take everything that you need with you.
>
> I really don't think that you will be able to get it all on two boats if you plan to winter there.

2. At the first stop on the journey the supplies are checked. The student is supplied with a list of items of which insufficient amounts were chosen and the minimum amounts required of these items. The student must then return to Churchill to choose supplies resulting in a loss of time.

Results

None of the students accessed the `GET HELP' section. When questioned about this one student responded, "I did not know what it would do." The researcher pointed out to the group while they were choosing supplies that there might be some help available if they tried `GET HELP.' Seven students accessed the advice section through 'GET HELP' after this option was pointed out to them.

No student attempted to do the mathematics called for in the chief factor's advice although seven recognized it was the valuable advice. The one line that was remembered by two students was: "A little grease goes a long way." No student attempted to manipulate the kilogram amounts chosen for each item so that they could take the maximum number of kilograms. Four out of the eight students manipulated the litre amounts to take the maximum allowed. One student did not understand that in some cases it is necessary to decrease some supplies in order to increase others. The researcher had to demonstrate this to this student, who then was able to increase and decrease supplies as needed.

All eight students guessed on the amounts to take. When the amounts were checked at the first stop all eight students used the listed minimums as the amounts to be chosen when they returned to Churchill to pick supplies again, even if they had not reached the maximum allowed. One student noted during the interview that if she were to do the program again she would try to take the maximum amounts.

Several students asked others what numbers they should choose. Students responded if the numbers happened to be on the screen at the time.

Seven students recorded the minimum amounts in their notebooks. The four students who did the program twice used these records to choose supplies the second time.

B. Other Supplies

In this section the students were supplied with a list of other possible supplies that might be needed for the journey. The list included guns, ammunition, fine dinnerware, nets, sheet iron stove, silverware, conjurors, oil lamps, table, blankets, knives, tablecloths, needles/beads, and glass windows. (Incidentally, Rae did take glass windows for his winter house.) Students were to choose ten items to take. Again advice and a glossary were provided through the `GET HELP' option.

Results

One student enquired, "What's a conjuror?" Upon being asked by the researcher how he could find out, he responded, "Oh yeah, the glossary." Most students were then observed accessing the glossary to find the definition of conjuror (a kind of kettle) and, as noted in their student notebooks, all eight correctly chose to take it.

Several students were observed accessing the advice section for 'other supplies'. Two commented that they took items to trade with the natives because of the advice. According to the notebooks all students did take items to trade.

2. Cloze Technique

In this section students filled in missing letters in two screens of wildlife reports. Each of the two reports was based on a creature the student had seen on the journey. Each student saw three creatures randomly selected by the program from a group of about eight. Facts used in the reports were drawn from the descriptions of the creatures in the wildlife lists. Students were instructed to check the wildlife list as each animal was presented during the journey because they would have a report to make upon completion of the journey. The missing letters were not chosen at random but were selected to encourage the student to think about and remember the facts s/he encountered in the wildlife list. The wildlife list was not available when the student was filling out the report.

Results

All students were observed to guess the letters in this section. One student when asked by another how to do this section said, "Try all the letters on the keyboard." Comments such as: "This does not work. I've tried every letter on the keyboard." indicated that this was the standard solution One student indicated that she did not look at the wildlife list at all. The database table above (Table 1) indicates that at least one other student did not access the wildlife list and one student accessed it only once. Two students (#5 and #8) commented during the interview that next time they would check the wildlife list each time they saw an animal so that they would know something about it and not get stuck when doing the report.

3. Deciding When To Put To Sea

After each stop the students were required to decide on an appropriate time to leave. They were given the choice of leaving or waiting until the weather conditions improved. In order to check the current weather conditions it was necessary to access the database. Depending on the location,weather conditions were chosen at random by the program within specific parameters. The optimum conditions included winds that were light or non existent or blowing away from shore, and high tide. If students chose to leave at an inopportune time the boats were damaged and time was lost repairing them. Students were then advised during the program to check the weather before leaving next time. The researcher did not point out the use of the database to any of the students in this particular context.

Results

Students 2, 3, 5, 6, and 8 all indicated frequent accessing of the weather database during the interview. Table 1 corroborates the statements made by 2 and 3. Students 3, 5, 6, and 8 all noted in the interview that they checked the weather upon leaving a place. Student 6 listed the best conditions to leave as "nice wind, high tide" and stated that "low tide is too shallow."

Student 1 indicated that although he wondered what the weather section meant he did not check it to find out. Student 7 listed the weather as a portion he checked but did not seem to understand why he accessed it or what it contained. The disk record indicated that the weather section was not accessed during the journey part of the program although it might have been accessed before that time. Not accessing the weather did not appear to affect their success in completing the program. Student 4 indicated that she accessed the weather only once which matched with the records. As she exceeded the maximum time allowed to reach Repulse Bay by eleven days the weather may have been a factor in her performance.

Transfer of Skills

During the interview one question was asked to determine whether or not the heuristic of gathering all available information before making a decision might transfer to another setting. The question was: Suppose you were travelling to a place called Okura with your family for a holiday. You are in charge of making the family clothing list. How would you decide what clothing to take?

Results

Students 1,3,5, and 7 all listed warm clothing. When asked why all had assumed the place was cold they replied that it was because we had been working with a simulation that took place in northern Canada.

Students 2, 4, 6, and 8 all asked where Okura was and what the weather would be like there before making a decision. The remaining four (1,3,5, and 7) recognized the importance of this information when it was drawn to their attention.

Analysis

Students used three primary methods to solve problems in the areas described above: guessing, gathering all pertinent information before making a decision, and asking other students. Guessing was the method most frequently used. Students persisted in this method even when other options, such as mathematical advice from the chief factor, were available. The following factors appeared to have an affect on the method chosen:

1. The kind of information available.

   When the information required mathematical manipulation, as in the advice of the chief factor, the students avoided using the information. They preferred to guess. The fact that the advice was in the form of an arithmetic problem may have been a factor, as the only part remembered from the advice was the words "a little grease goes a long way". Although all students could do the mathematical calculations required, mathematical skills did not transfer to this situation.

   When the information was in the form of a glossary or a weather report, both familiar and text-based, students appeared to be more inclined to use it. In choosing other supplies most students did obtain relevant information before making a decision. Students appeared comfortable with accessing the glossary. One factor may be their familiarity with dictionaries and glossaries under ordinary circumstances. In this case it appears that for some of the students the skill of using a dictionary or glossary did transfer to the new computer situation. In the case of the weather report a factor may be that by this time in the program students may have been more used to the idea of using a database as an information tool and therefore used it more effectively.

2. Recognition that a problem exists. In the section where the student was to access the wildlife list the problem of the cloze passage report was not yet evident and several students did not access the wildlife list. This may have been due to students not recognizing that a problem would shortly exist and taking no action to prepare to solve it. Two student noted that they would do things differently the next time they played.

3. Existence of an alternate solution

In the choosing food and fuel supplies section, students quickly recognized, through their own discovery or from observing others, that they would be told the minimum amounts of food and fuel upon their arrival at the first stop if their original guesses were incorrect. Although a time penalty was involved, students clearly preferred this solution to the task of solving the mathematical problem. Providing a 'way out' may have reduced frustration levels for the students but this alternative may have permitted students to avoid the more difficult mathematical solution.

The student use of the glossary and the weather reports as well as the ability of four of the students to gather information on an unfamiliar place before deciding on appropriate clothing suggest that some general problem-solving skills such as gathering all pertinent information before making a decision do exist and may be transferrable.

I suspect that successful teaching of problem-solving skills may involve direct instruction by the teacher. Students made no attempt to access the database as a source of knowledge until prompted to do so. Once prompted, students accessed it frequently. When questioned about using the database six students indicated frequent access of the database as a source of information giving examples such as:
Student 5: "checked when leaving a place."
Student 3: "helped with words like ebb tide"

II. Metacognition

In this section metacognition will be discussed under two headings: students' metacognitive skills, and the effectiveness of the simulation as a motivating tool to promote metacognitive skills

A. Students' Metacognitive Skills

As noted previously, metacognition is a candidate for becoming seen as a general problem-solving skill. The following metacognitive skills, as described by Gagné (1985) and reflecting Polya's influence, will be discussed: student understanding of the task goal; student knowledge of appropriate learning strategies; student selection of appropriate learning strategies; and student self-monitoring.

Results

1. Understanding of the Task Goal

The students were asked what the purpose of the program was. Five of the students noted that the main thing to be learned from this program was content, including information about John Rae, the animals, geography, explorers, difficulties of navigation, the Northwest Passage, northern conditions, and how to travel in the north.

Three of the students (2,4, and 6) said the program was really about decision-making.

2. Knowledge of appropriate problem-solving strategies

As noted in the discussion on heuristics used by the students the three primary methods used to solve problems were: guessing, gathering all pertinent information before making a decision, and asking other students.

3. Selection of appropriate problem-solving strategies

Selection of appropriate strategies is examined by the student rate of success in completing the program within the required time.

The following table lists the number of attempts at the program, the number of days required to complete the journey, and whether or not the student succeeded in completing the journey to Repulse Bay within the required time. The maximum time allowed to complete the journey is 37 days.

TABLE 2

Student	Attempt	No. of Days	Arrived Repulse Bay	Success/Failure
1	1	31 days	yes	success
2	1	25 days	yes	success
3	1 2	47 days 35 days	yes - too long yes	failure success
4	1	48 days	yes - too long	failure
5	1 2	44 days 26 days	yes - too long yes	failure success
6	1 2	39 days 29 days	yes - too long yes	failure success
7	1	27 days	yes	success
8	1 2	unknown 26 days	no-men drowned yes	failure success

Students (with one exception) who did not succeed in reaching Repulse Bay in the required time the first time were offered the opportunity to try again. The other option was to return to the classroom. All preferred to try the program again. The exception was student #4 who was the last to finish and, therefore, did not have the time to try again.

4. Self-monitoring

Students were asked why they either failed or succeeded in reaching Repulse Bay in the required time.

Seven out of the eight students commented on the choosing of supplies as a factor in their success or failure. Four students (2, 5, 6, & 7) indicated that they used the advice to successfully decide what to bring in the way of supplies. Two students (3 &8) admitted to remembering the correct supplies from the previous attempt. All four students on the second attempt were observed using notes from the previous attempt to choose supplies. One student (1) did not comment on the supplies at all. One student (4) said that going back for supplies many times was a reason for her failure.

Two students (3 & 7) stated that checking the weather before leaving was a factor in their success. One pointed out that he made the checks on the second attempt as a result of what the program said when he left in bad weather on the first attempt.

The one student (4) who did not succeed in reaching Repulse Bay in the required time cited having to go back for food, damaged ships, and bad storms as reasons for her failure.

One student (5) commented on learning how to deal with storms as a factor in his success. Another (8) commented on knowing when to stop for a rest.

One student (1) stated that he was successful because he took his time and read the letter from the admiralty.

Analysis

Three students did recognize that improving decision-making skills (or problem-solving skills) was an underlying goal of the program. None of the students verbalized as a goal the learning of the general problem-solving technique of gathering all available information before making a decision. The other five students focussed on learning the content of the program as the main goal.

Our traditional emphasis in schools on knowledge and comprehension as a learning goal rather than on problem-solving skills such as analysis, synthesis, and evaluation may be a factor in these students' focus on content. It is encouraging to note that three students did recognize decision-making as an underlying goal even though they were unable to verbalize the specifics of the goal.

Although students did not say that learning to gather all available information before making a decision was a goal, it is apparent some of them did achieve this goal as indicated in the discussion of domain-specific and general problem-solving skills.

At least four of them recognized the use of this skill as an element of their success in choosing supplies and two of them noted its success in deciding on appropriate weather conditions for leaving. In addition, several used this skill in the interview when asked to choose suitable clothing for a family trip indicating that this skill may not be context-bound.

It is apparent that most of these students possessed some metacognitive skills. The study suggests that direct instruction in and modelling of these skills by the teacher may be an important element in training students to think about thinking. Students could be provided with a variety of strategies to use when solving problems prior to attempting the program. Debriefing could focus on which strategies were chosen, why they were chosen, and whether or not they were successful. Group discussion may be an effective technique allowing students to observe the metacognitive skills of the teacher and other students.

B. The Simulation as a Motivating Tool

Ryba (1989) has suggested that the ecological approach to learning may promote metacognitive skills. Motivating simulations may be an effective part of this approach. The John Rae simulation is examined below as a possible tool to provide a motivating learning environment in which students are encouraged to examine their own thinking. This analysis will take place through an examination of student reaction to the simulation.

Results

Student Reaction to the Simulation

The students' reactions to the program were inferred from student on-task and off-task time, the comments made about the program in general, the comments made about the portions of the program the students found frustrating, and the student reaction to the use of colour.

On-task and Off-task Time

All students began the simulation at 10:43 am. We broke for lunch at 12:00 and resumed work at 1:17 pm ending the simulation at 2:35 pm. When offered an extra 15 minutes at 1:45 pm all accepted eagerly. The following table lists the students' on-task and off-task time.

TABLE 3

Student	On-task Time (min)			Off-task Time (min)		
	am	pm	total	am	pm	total
1	43	48	91	34	0	34
2	77	33	110	0	0	0
3	67	33	100	0	0	0
4	77	78	155	0	0	0
5	77	41	118	0	0	0
6	72	37	109	0	0	0
7	77	31	108	0	0	0
8	77	48	125	0	0	0
Means	70.9	43.6	114.5	4.3	0	4.3

Three students were scheduled to leave for school patrol at 11:25 but all requested a substitute when the patrol leader came to get them. Student 1 chose to leave the morning session at 11:26 for his usual physical education time with the explanation, "I need to run off energy." His attendance at the physical education session was voluntary. None of the other students was scheduled to go. This accounts for the 34 minutes off-task time in the above table.

No student chose to look at the additional print materials provided.

General Reaction to the Program

Casual comments such as the following indicated the students' enthusiasm:

Student 2: "This is neat!"

Student 3: "This is neat. I like this trout."

Student 4: "This is neat. I like it."

Student 6: "This is fun!"

"Alright! I'm there!"

"This is great!"

During the interview all students responded "yes" to the question "Did you like the program?" The most frequently cited reasons were:

"challenging"(4 students),

"You get to make decisions"(4 students), "It was exciting/adventurous/fun (4 students).

Two students thought it was "interesting" and one commented on the feedback - "You got to see if you were right or wrong."

Reaction to Frustrating Portions

Not all the comments about the program were positive. Two parts of the program in particular, choosing supplies and the wildlife report cloze passages, caused frustration.

Choosing the correct amounts for the supplies was a difficult task for the students. If the correct amounts were not chosen the students were sent back to Churchill to get them resulting in a loss of time. During the interview five out of the eight students described choosing supplies as either a difficult or a challenging part of the program. One student had no comment while two others, while working with the simulation, commented on the difficulty of this portion. Typical comments were:
"Oh no, I have to go back."
"This is getting tiring. I have to go back again!"

All students did succeed at choosing supplies and several expressed their relief with comments such as:
"I finally made it past the supplies."
"I had to go back five times but I made it."

The other portion that caused frustration was the cloze passages used in the wildlife report. Six out of the eight children, when interviewed, said they had difficulty with the cloze passages in the wildlife report. One of the two remaining students was observed commenting on the difficulty of this section during the simulation. The final student had no comment on this portion. Typical comments about this were:

"I'll guess anything."

"I can't get this word. This does not work. I've tried every letter on the keyboard."

"How do you get out of this?"

Although students were permitted to go on to the next page with 80% of the blanks filled in correctly two students indicated that 100% was important to them and refused to go until all the letters were solved. Their comments of "I got it!" and "I really wanted 100%" indicated their pleasure at their success. All students succeeded in completing the two pages. The six who pointed out the difficulty in this section all commented on their success. One student said, "I guessed the letters and I finally got it."

Other students described deciding when to put to sea according to the weather and how to deal with storms as challenging.

Student Reaction to Colour

All students used a colour monitor but no comments were made on the colour during the simulation. When asked about colour at the interview three students indicated that it would matter because colour was more attractive and added an element of realism. The other five students said colour made no difference.

Analysis

It is clear that the students found this simulation to be motivating. Although other options such as patrol duty, examining the printed materials, and returning to the classroom, were available to them, they all chose to work with the program. The total amount of time spent on the program ranged from 91 minutes to 155 minutes with a mean time of 114.5 minutes per student. During this time all students were involved with the program. In addition, the four students (3, 5, 6, and 8) who were offered the opportunity to try the program again accepted. The remaining four were not offered the opportunity because of a lack of time.

It is more difficult to establish what factors made it motivating. Some possibilities are the following:

1. The interactive nature of the program. The positive comments by four of the students on the decision making aspect of the program suggest that interaction was an important factor to them. As one student put it "You get to have choices - not

just one thing." One student noted that the immediate feedback was an important part of the interaction. They showed no interest at all in the non interactive reading materials.

2. The challenging nature of the program. Some frustration may be a factor in providing challenge in a simulation. The choosing supplies section and the wildlife cloze passages appeared to provide this frustration and, therefore, the challenge.

Although the students were frustrated by the above named portions of the programs no student indicated that anything was impossible. Their general reaction was pride at having succeeded. One student pointed out, "I knew I'd accomplished something." I suspect that a program that does not provide some challenge and frustration will be too easily mastered and will quickly become boring. The difficulty from the design point of view will be finding a balance between challenges that are within the students' range of abilities and those which most students will find impossible. Teachers will have to be aware of the types of activities present in particular packages and choose materials that are challenging and yet within the students' range of abilities.

As Ryba (1989) has pointed out motivating software may be an important factor in developing an ecological environment in which metacognition can be encouraged as a general problem-solving skill. I suspect that students who find a simulation to be motivating may spend extensive time and energy working on it, trying to solve the problems, as did the students in this study. In addition, the motivating or challenging aspects of the program will likely be most effective in teaching metacognitive skills if the problems presented provide intrinsic rewards for using appropriate strategies. The John Rae simulation appeared to be at least partly successful in this. For example, students who accessed the weather database and chose appropriate times to leave were rewarded with short travel times.

As the students did not experience both monochrome and colour screen it is difficult to make any inferences about colour.

III. Cognitive Style

Matching Familiar Figures Test

The following tables list student scores on the Matching Familiar Figures Test.

Table 4
Matching Familiar Figures Pretest

Student	Mean Response Latency	Mean Errors	Classification
1	3.01	.67	fast/accurate
2	5.47	1.08	fast/accurate
3	2.18	1.25	fast/accurate
4	2.13	1.92	fast/accurate
5	2.40	1.00	fast/accurate
6	7.05	.75	fast/accurate
7	3.57	1.17	fast/accurate
8	6.01	.75	fast/accurate

Table 5
Matching Familiar Figures Posttest

Student	Mean Response Latency	Mean Errors	Classification
1	1.95	1.17	fast/accurate
2	2.76	.34	fast/accurate
3	1.97	1.08	fast/accurate
4	2.44	.75	fast/accurate
5	1.50	1.08	fast/accurate
6	4.29	.75	fast/accurate
7	2.88	.75	fast/accurate
8	6.77	.25	fast/accurate

All students scored as fast/accurate on both the pretest and the posttest and, therefore, could not be classified as either impulsive (fast/inaccurate) or reflective (slow/accurate). As there were no students at either end of the continuum, the test did not provide information relevant to this study.

IV. Cooperative Learning

Students were not encouraged to work in groups or pairs as each had his/her own computer and program with which to work. They were told that they could ask the researcher for help. No attempt was made to stop students from discussing the program with each other.

Spontaneous peer interaction was observed frequently during the simulation.

Although competition was not mentioned at any point students frequently compared their progress with comments such as:

Student 2: "I'm at Wager River."

"I made it past the supplies."

Student 3: "I'm in Repulse Bay."

Student 4: "Where are you, Kevin?"

Student 5: "My duck doesn't taste good."

Students watched and questioned each other on how problems were to be solved.

Student 1: "Are you supposed to find out what animal this is?"

"What is fatigue?"

Student 2: "Why are you observing weather? To see when to go?"

Student 3: "How do you get out of this?"

Student 4: "How did you get there? What did you do?"

Student 8: "What if you say 'no'?"

Students generally answered questions addressed to them briefly. Examples were:

"I just typed all the letters on the keyboard until I got it.

"I just guessed."

"Check the weather before you go or you'll get in trouble."

"Get advice."

Student 3 attempted to help student 4 on the cloze passage by typing on her keyboard. Student 4 would not permit him to touch it but accepted verbal instructions.

Students were observed to simply provide the answer. In some cases, students explained the method used to obtain the answer.

Students 1 and 8 asked the instructor many questions. Student 8 needed a lot of assistance in following the directions on the screen. She needed help in using the arrows to increase and decrease the quantities when choosing supplies. She also needed assistance in using latitude and longitude to establish locations.

Student 7 rarely asked questions but did listen to and observe the other students near him.

Student 4 frequently asked for help from the others and watched what they were doing.

Analysis

Spontaneous peer interaction was one of the most striking features of this study. Short of physically isolating each child it would have been impossible to prevent it. It appeared to be a natural outcome of working with the simulation. The public nature of the computer screen may have been one contributing factor in the spontaneous interaction. Students frequently leaned over to check each others' progress and to watch how others solved problems. Another factor may be the motivating nature of the simulation. Students were very eager to share both their successes and problems. Students appeared to take pride in telling others how they solved the problems.

Cooperative learning was evident in the peer interaction between the students. Students both asked and answered questions of each other. Student discussion was consistently on topic dealing with issues such as how to solve problems and the progress students were making. Although in some cases students simply provided the other student with the answer without taking the time to explain the method chosen they frequently provided a brief description of the method. This study suggests that cooperative learning appears to have potential to be an effective tool in teaching and applying metacognitive skills. Students modelled and explained the strategies they used to solve problems. Students learned from each other by adopting the strategies that were modelled.

The strategies ranged from guessing to accessing the database for additional information. There was little, if any, discussion about the effectiveness of the various strategies. I suspect that students used the simplest strategies and avoided complicated ones such as those involving mathematical manipulation. Teacher intervention in the form of modelling and discussing effective problem-solving techniques may be necessary to promote appropriate strategies.

Chapter 5 - Conclusions

From the information obtained in this study five topics appear to merit further consideration as they appear to be factors that had an influence on students' problem-solving behavior in the context of a highly interactive computer simulation. The students' persistent use of guessing as a problem-solving technique provided some insight into problem-solving. The students' response to this simulation suggested some techniques that may help to make simulations effective problem-solving tools. Limited student frustration and the type of interaction present in cooperative learning appeared to be factors in the simulation that had an effect on student problem-solving skills. In addition, the role of the teacher appeared to be an important factor. All five factors suggested avenues for further research.

Guessing as a Problem-solving Technique

As was pointed out in the previous chapter guessing was the method frequently chosen to solve problems. The circumstances under which students guessed provided some clues as to why students may have persisted in this method.

When choosing food and fuel supplies, students persisted in guessing despite the presence of another option recognized by all students to be valuable. I suspect that the students' reluctance may have been based on the type of information presented. The advice called for a relatively complex mathematical manipulation. In addition to avoiding the mathematics in the advice the students also avoided manipulating the amounts chosen of each item so as to match the total amount allowed. Again, they appeared to be avoiding mathematics. In contrast, when choosing other supplies and when checking the weather, the information was in discursive form and students did make use of it. This apparent preference for text-based information over mathematical manipulation raises several questions. In other situations, do students generally prefer discursive information over mathematical information? Is the complexity of the mathematics a factor? Would students have used the mathematical advice if there had been a single time frame for consumption of supplies rather than two time frames? (e.g. pemmican was to last for four months but all other supplies were to last for one year)

In the cloze passage students were often forced to guess at the missing letters because they had not accessed the wildlife list previous to attempting the wildlife report. The program did inform the students, when they were looking at the wildlife, that a report would have to be completed at the end of the journey. The wildlife list was not available while the students were completing the cloze passage. Earlier speculation pointed out that students may not have recognized that a problem would shortly exist and therefore did nothing to prepare for it. Even if students had recognized the existance of a problem or if the wildlife list had been available during the cloze passage I suspect that many students may have continued to guess. Guessing in this section was a simple technique that invariably produced success with varying degrees of efficiency. Would students attempt another problem-solving technique such as gathering additional information when a simple, successful although somewhat inefficient, technique was already apparent?

Student Reaction to the Simulation

One of the most striking aspects of this study was the student enthusiasm for the simulation. Some student enthusiasm is likely accounted for by the Hawthorne effects and it was to some extent novel. Students clearly felt special in being chosen to be part of this project. A relatively simple method of checking for the Hawthorne effects would be to integrate the software package into the regular classroom curriculum and observe student reaction. I suspect that the students' positive reaction included such factors as the effects of cooperative learning and the challenging nature of this program.

Spontaneous peer interaction appeared to be a natural outcome of using this simulation. This interaction seemed to intensify the students' enjoyment as they shared their experiences and compared progress. Their enthusiasm was particularly marked by the entensive period of on-task time. Would students working alone on this simulation isolated from other students experience the same enthusiasm and would they concentrate on the simulation for as long a period of time? Would pairing students on the simulation serve to increase or decrease the on-task time? Is there an optimum group number that will effectively maintain interest and on-task time?

As noted earlier students appeared to be frustrated and challenged by this program. I suspect that students would quickly become bored with a program that did not provide these elements. Examination of other simulations may provide answers to questions such as: What kinds of activities do students find challenging in simulations? Do simulations that students classify as non challenging or "easy" motivate students?

Limiting Student Frustration

While some frustration appears to be useful in creating a challenging simulation, there is a fine line between a challenging situation and an impossible situation. The position of this line varies according to the abilities of the student. How should instructional designers deal with this problem? This simulation provided a 'way out' for the student in the most frustrating section - choosing food and fuel supplies. If students guessed the supplies incorrectly the minimum amounts needed were provided at the first stop. I suspect that this 'way out' may have affected how the students dealt with the problem of the choosing supplies. The existance of this 'way out' quickly became common knowledge through student communication. Students readily accepted the time penalty in return for a simple solution to the problem. If this 'way out' did not exist would students have become frustrated to the point of quitting or would students have been forced to attempt the mathematics in the chief factor's advice?

Interaction in Cooperative Learning

In peer interaction, students modelled their problem-solving skills and pointed out some problem-solving techniques for other students. Although this suggests that simulations may be effective tools for promoting metacognitive skills, more attention may need to be paid to the qualities of this type of student interaction. It is noteworthy that although students modelled and described problem-solving techniques, none of the students discussed the effectiveness of their solutions nor did they usually explain why a particular method of solution was chosen. In some cases students simply provided the answer without any explanation. Would pre-training in metacognitive skills promote more discussion of solution selection and effectiveness and therefore more learning? Would assigning a particular student in a group the task of asking why a solution was chosen and whether or not it was successful be an effective technique to promote better metacognitive skills?

The Role of the Teacher

The role of the teacher appeared to be an important factor in all aspects of this study. Although it was apparent that students were capable of metacognitive skills, they did not appear very often until after teacher intervention. Students needed assistance in defining the more subtle goals of the programs such as practicing specific problem-solving skills. Most appeared to be unaware of strategies other than guessing that could be used . Students seemed to require guidance in evaluating their problem-solving skills for effectiveness. Further study of techniques that teachers may find effective in promoting problem-solving skills is suggested. The teacher's role in this kind of situation may be that of a facilitator. S/he may provide instruction and models of appropriate problem-solving techniques before the simulation is attempted. Guidance during the simulation with emphasis on evaluation of progress may be effective. Debriefing students upon the completion of the program to evaluate student's problem-solving techniques may help to focus students on metacognitive skills.

References

Alessi, Stephen M, & Trollip, Stanley R. (1985). Computer Based Instruction - Methods and Development. Prentice-Hall, Inc. Englewood Cliffs, NJ.

Baron, J. (1985). What Kinds of Intelligence Components are Fundamental? In S.F. Chipman, J.W. Segal, and R. Glaser (Eds.) Thinking and Learning Skills, Vol. 2: Research and Open Questions. Lawrence Erlbaum Associates, Hillsdale, NJ.

Barcey, G.W. (1982). Computers in Education: What the Research Shows. Electronic Learning, Vol.2, pp. 51-54.

Brown, John Sealy. (1985). Idea Amplifiers - New Kinds of Electronic Learning Environments. Educational Horizons, Spring 1985.

Bruner, Jerome. (1985). On Teaching Thinking: An Afterthought In Chipman, Susan F., Segal, Judith W. and Glaser, Robert (Eds.) Thinking and Learning Skills Volume 2 Research and Open Questions. Lawrence Erlbaum Associates, Inc. Publishers Hillsdale NJ.

Chipman, Susan F. (1985). Introduction to Volume 2: Research Trends and Their Implications. In Chipman, Susan F., Segal, Judith W. and Glaser, Robert (Eds.) Thinking and Learning Skills Volume 2 Research and Open Questions. Lawrence Erlbaum Associates Inc., Hillsdale NJ.

Cosden Meridith A. & Lieber Joan. (1986). Grouping Students on the Microcomputer. Academic Therapy 22:2.

Eiser, Leslie. (1986). Problem-solving Software: What It Really Teaches. Classroom Computer Learning, March 1986, pp.42-44.

Flake, J.L., McClintock, C.E., and Turner, S.V. (1985) Fundamentals of Computer Education. Wadsworth, Belmont, CA.

Gagne, Robert M. and Glaser, Robert (1987). Foundations in Learning Research in Instructional Technology Foundations. Lawrence Erlbaum Associates, Publishers, Hillsdale, NJ.

Gagne, E.D. (1985). The Cognitive Psychology of School Learning. Little, Brown and Company, Boston, MA.

Glaser, Robert. (1985). Learning and Instruction: A Letter for a Time Capsule. In Chipman, Susan F., Segal, Judith W. and Glaser, Robert (Eds.) Thinking and

Learning Skills Volume 2 Research and Open Questions. Lawrence Erlbaum Associates, Inc. Publishers Hillsdale NJ.

John Rae I - The Journey Begins. (1988). Manitoba Computer Assisted Learning Consortium. Winnipeg, MB.

Kagan, Jerome (1984). The Nature of the Child. Basic Books Inc., Publishers. New York, NY.

Lockard, James, Abrams, Peter D., and Many, Wesley A. (1987). Microcomputers for Educators. Little Brown and Company, Toronto,ON.

Messick, Samuel (1976) Personality Consistencies in Cognition and Creativity. In Messick, Samuel and Associates (1976). Individuality in Learning. Jossey-Bass, Inc., Publishers, San Fransisco, CA.

Moursund, David. (1988). Problem Solving. The Computing Teacher, Vol. 16, No. 4. pp. 5. University of Oregon, Eugene, OR.

Mussen, Paul Henry, Conger, John Janeway, Kagan, Jerome. (1979). Child Development and Personality. Chapter 6 Cognitive Development. Harper and Row, Publishers, New York, NY.

Nickerson, Raymond S., Perkins, David N. and Smith, Edward E. (1985). The Teaching of Thinking. Lawrence Erlbaum Associates, Hillsdale, NJ.

Polson, Peter G. & Jeffries, Robin. (1985). Instruction in General Problem-Solving Skills: An Analysis of Four Approaches. In Chipman, Susan F., Segal, Judith W. and Glaser, Robert (Eds.) Thinking and Learning Skills Volume 1 Relating Instruction to Research. Lawrence Erlbaum Associates Inc., Hillsdale NJ.

Mineo, Beth A. & Cavalier, Al R. (1985). From Idea to Implementation: Cognitive Software for Students with Learning Disabilities. Journal of Learning Disabilities, Vol. 18, No. 10, pp. 613-618.

Norton, Priscilla & Resta, Virginia. (1986). Investigating the Impact of Computer Instruction on Elementary Student's Reading Achievement. Educational Technology, March 1986.

Papert, Seymour. (1980). Mindstorms, Children, Computers, and Powerful Ideas. Basic Books, New York, NY.

Pogrow, Stanley. (1987). Developing Higher Order Thinking Skills: The HOTS Program. The Computing Teacher, August/September, 1987, pp. 11-15.

Polya, George. (1957). How To Solve It (2nd ed.). Princeton University Press Princeton, NJ.

Ryba, Ken. (1989). Learning with Computers - Effective Teaching Strategies. (In Press).

Ryba, Ken. (1988). An Ecological Perspective on Computer in Special Education. Paper presented to a Faculty Seminar, Faculty of Education, University of Manitoba, Winnipeg, MB.

Scardamalia, Marlene, Bereiter, Carl & McLean, Robert S. (1988). Computer-Supported Instructional Learning Environments. Ontario Institute for Studies in Education, Toronto, ON.

Shank, Roger C. (1984). The Cognitive Computer. Addison-Wesley Publishing Company Ltd.,Reading, MA.

Simon, H.A. (1980). Problem Solving and Education. In D.T. Tuma and F. Reif (Eds.), Problem Solving and Education: Issues in Teaching and Research. Lawrence Erlbaum and Associates, Hillsdale, NJ.

Sternberg, Robert J. (1985). Teaching Critical Thinking, Part 1: Are We Making Critical Mistakes? Phi-Delta-Kappan, Vol. 67 No. 3, November 1985.

Sternberg, Robert J. (1985). Teaching Critical Thinking, Part 2: Possible Solutions. Phi-Delta-Kappan, Vol. 67 No. 4, November 1985.

Tennyson, Robert D. & Thurlow, Richard. (1987). Problem-Oriented Simulations to Develop and Improve Higher-Order Thinking Strategies. Computers in Human Behavior, Vol. 3, pp. 151-165. Pergamon Press.

Webb, Noreen M. (1987). Peer Interaction and Learning with Computers in Small Groups. Computers in Human Behavior, Vol. 3, pp.193-209. Pergamon Press.

Williams, Harvey D., McLean, Cheryl L., Bochonko, Helen. (1986). A LISP-based Intelligent Tutorial for Microcomputers. Proceedings of the Fifth Canadian Symposium on Instructional Technology. National Research Council of Canada.

Woodward, John, Carnine, Douglas & Gersten, Russell. (1988). Teaching Problem Solving Through Computer Simulations. American Educational Research Journal, Vol. 25, No. 1, pp. 72-86.

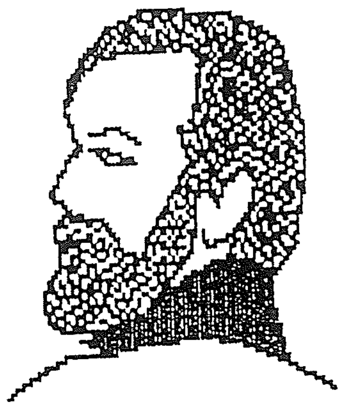
Wright, E.B., & Forcier, R.C. (1985) The Computer: A Tool for the Teacher. Wadsworth, Belmont, CA.

Yates, Billy C. & Moursund, David. (1988). The Computer and Problem Solving: How Theory Can Support Classroom Practice. The Computing Teacher, Volume 16, Number 4, pp. 12-16. University of Oregon, Eugene, OR.

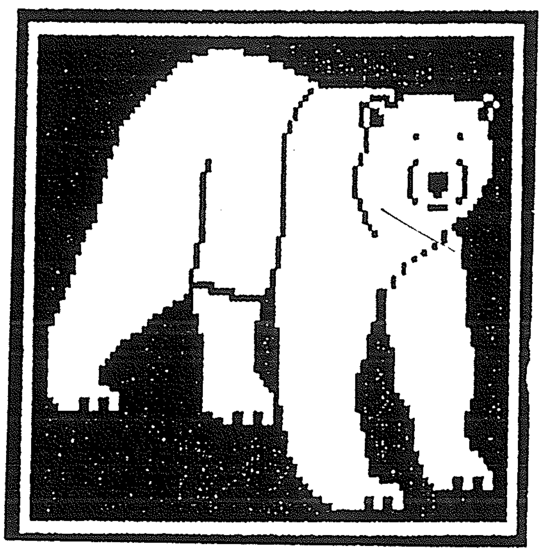
Appendix A

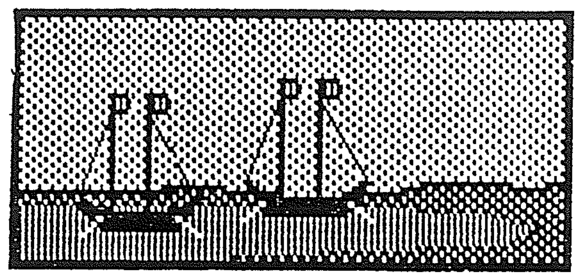
STUDENT NOTEBOOK

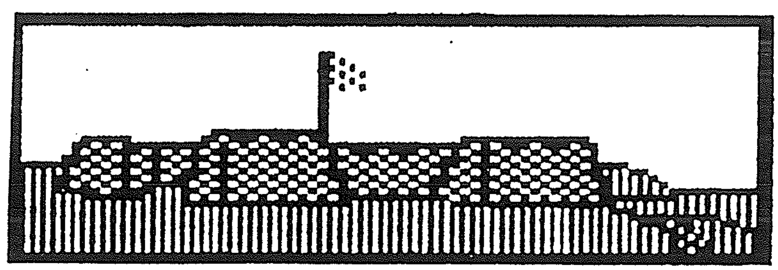
John Rae I



The Journey Begins







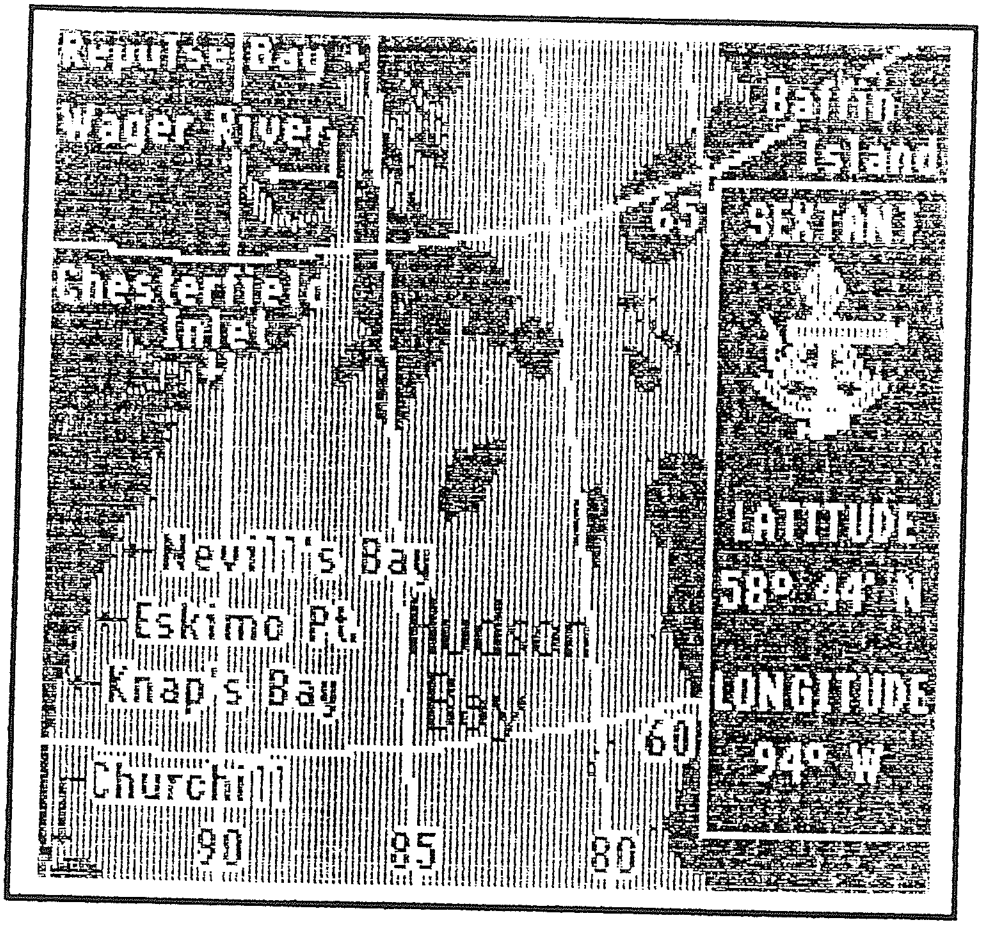
Supply Lists

Food and Fuel	
Item	**Amount Taken**
Pemmican	
Grease	
Flour	
Tea	
Sugar	
Chocolate	
Fuel alcohol	
Brandy/wine	

Record the amounts taken of each item.

Other Supplies	
Guns	
Ammunition	
Fine dinnerware	
Nets	
Sheet iron stove	
Silverware	
Conjurors	
Oil lamps	
Table	
Blankets	
Knives	
Tablecloths	
Needles/beads	
Glass windows	

Place a checkmark beside the other supplies taken.



Circle the places where you stopped and record the date.

Place	Date

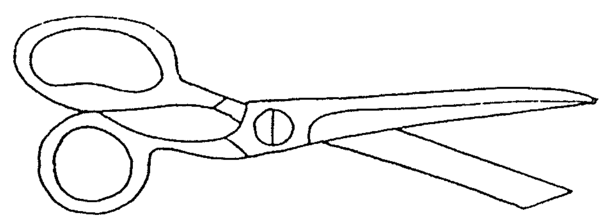
Diary

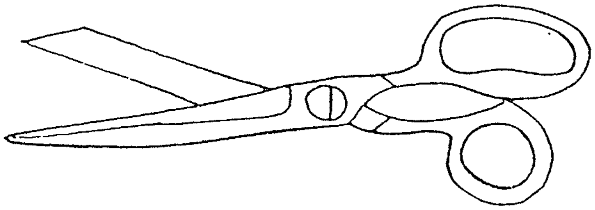
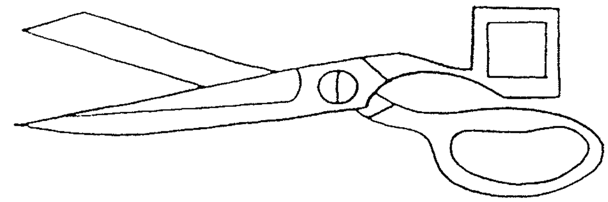
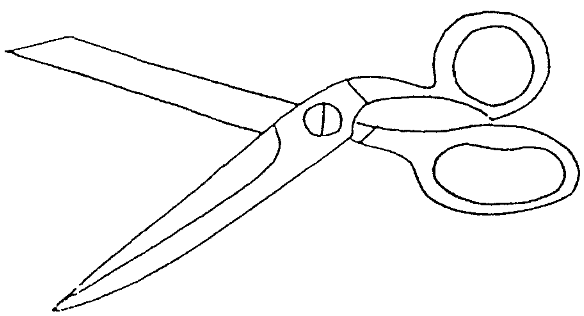
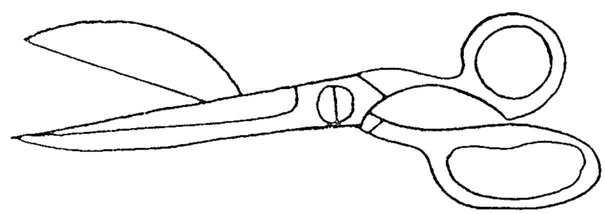
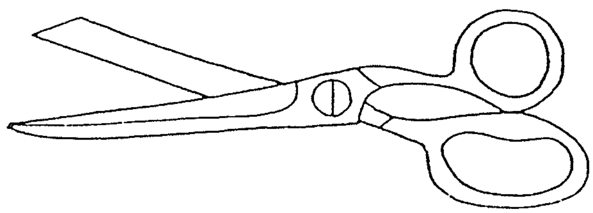
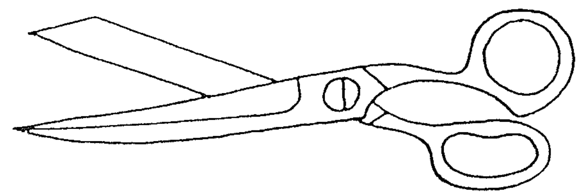
Date	Event

Diary

Date	Event

MATCHING FAMILIAR FIGURES TEST



Student Record

Time

	Program	Readiings		Program	Readings
Start Time	________	________	Start Time	________	________
End Time	________	________	End Time	________	________

	Program	Readings		Program	Readings
Start Time	________	________	Start Time	________	________
End Time	________	________	End Time	________	________

	Program	Readings		Program	Readings
Start Time	________	________	Start Time	________	________
End Time	________	________	End Time	________	________

Program Completion

Attempt	Time	Event	Student Comments

General Observations

____

____

____

____

____

____

____

____

____

____

____

____

____

____