1993

Developing problem solving abilities with artificial intelligence.

Frederic. Riviere
University of Windsor

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DEVELOPING PROBLEM SOLVING ABILITIES WITH ARTIFICIAL INTELLIGENCE

by

Frédéric Rivière

A thesis
Submitted to the Faculty of Graduate Studies and Research
through the Faculty of Education in
Partial Fulfilment of the Requirements for the
Degree of Master of Education at the
University of Windsor

Windsor, Ontario, Canada

1993

ISBN 0-315-93307-0

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  - Linguistique 0290
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  - Anciennes 0294
  - Comparée 0295
  - Médiévale 0297
  - Moderne 0298
  - Africaine 0316
  - Américaine 0591
  - Anglaise 0593
  - Asiatique 0305
  - Canadienne (Anglaise) 0352
  - Canadienne (Française) 0355
  - Germanique 0311
  - Latino-américaine 0312
  - Moyen-orientale 0315
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  - Généralités 0501
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  - Histoire 0509
  - Théorie 0511
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- Études canadiennes 0385
- Études féministes 0453
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- Géographie 0366
- Gérontologie 0351
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  - Généralités 0310
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  - Comptabilité 0272
  - Marketing 0338
- Histoire
  - Histoire générale 0578
  - Ancienne 0579
  - Médiévale 0581
  - Moderne 0582
  - Histoire des noirs 0328
  - Africaine 0331
  - Canadienne 0334
  - États-Unis 0337
  - Européenne 0335
  - Moyen-orientale 0333
  - Latino-américaine 0336
  - Asie, Australie et Océanie 0332
- Histoire des sciences 0585
- Loisirs 0814
- Planification urbaine et régionale 0999
- Science politique
  - Généralités 0615
  - Administration publique 0617
  - Droit et relations internationales 0616
- Sociologie
  - Généralités 0626
  - Aide et bien-être social 0630
  - Criminologie et établissements pénitentiaires 0627
  - Démographie 0938
  - Études de l'individu et de la famille 0628
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  - Structure et développement social 0700
  - Théorie et méthodes 0344
  - Travail et relations industrielles 0629
- Transports 0709
- Travail social 0452

SCIENCES ET INGÉNIERIE

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  - Agronomie 0285
  - Alimentation et technologie alimentaire 0359
  - Culture 0479
  - Élevage et alimentation 0475
  - Exploitation des pâturages 0777
  - Pathologie animale 0476
  - Pathologie végétale 0480
  - Physiologie végétale 0817
  - Sylviculture et faune 0478
  - Technologie du bois 0746
- Biologie
  - Généralités 0306
  - Anatomie 0287
  - Biologie (Statistiques) 0308
  - Biologie moléculaire 0307
  - Botanique 0309
  - Cellule 0379
  - Écologie 0329
  - Entomologie 0353
  - Génétique 0369
  - Limnologie 0793
  - Microbiologie 0410
  - Neurologie 0317
  - Océanographie 0416
  - Physiologie 0433
  - Radiation 0821
  - Science vétérinaire 0778
  - Zoologie 0472
- Biophysique
  - Généralités 0786
  - Médicale 0760

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- Géochimie 0996
- Géodésie 0370
- Géographie physique 0368
- Géologie 0372
- Géophysique 0373
- Hydrologie 0388
- Minéralogie 0411
- Océanographie physique 0415
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- Paléontologie 0418
- Paléozoologie 0985
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  - Audiologie 0300
  - Chimiothérapie 0992
  - Dentisterie 0567
  - Développement humain 0758
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  - Immunologie 0982
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  - Pharmacie 0572
  - Pharmacologie 0419
  - Physiothérapie 0382
  - Radiologie 0574
  - Santé mentale 0347
  - Santé publique 0573
  - Soins infirmiers 0569
  - Toxicologie 0383

SCIENCES PHYSIQUES

Sciences Pures

- Chimie
  - Généralités 0485
  - Biochimie 487
  - Chimie agricole 0749
  - Chimie analytique 0486
  - Chimie minérale 0488
  - Chimie nucléaire 0738
  - Chimie organique 0490
  - Chimie pharmaceutique 0491
  - Physique 0494
  - PolymÇres 0495
  - Radiation 0754
- Mathématiques 0405
- Physique
  - Généralités 0605
  - Acoustique 0986
  - Astronomie et astrophysique 0606
  - Électronique et électricité 0607
  - Fluides et plasma 0759
  - Météorologie 0608
  - Optique 0752
  - Particules (Physique nucléaire) 0798
  - Physique atomique 0748
  - Physique de l'état solide 0611
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  - Radiation 0756
- Statistiques 0463

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- Informatique 0984
- Ingénierie
  - Généralités 0537
  - Agricole 0539
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  - Chaleur et thermodynamique 0348
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  - Génie aérospatial 0538
  - Génie chimique 0542
  - Génie civil 0543
  - Génie électronique et électrique 0544
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  - Génie mécanique 0548
  - Génie nucléaire 0552
  - Ingénierie des systèmes 0790
  - Mécanique navale 0547
  - Métallurgie 0743
  - Science des matériaux 0794
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  - Technique minière 0551
  - Techniques sanitaires et municipales 0554
  - Technologie hydraulique 0545
- Mécanique appliquée 0346
- Géotechnologie 0428
- Matières plastiques (Technologie) 0795
- Recherche opérationnelle 0796
- Textiles et tissus (Technologie) 0794

PSYCHOLOGIE

- Généralités 0621
- Personnalité 0625
- Psychobiologie 0349
- Psychologie clinique 0622
- Psychologie du comportement 0384
- Psychologie du développement 0620
- Psychologie expérimentale 0623
- Psychologie industrielle 0624
- Psychologie physiologique 0989
- Psychologie sociale 0451
- Psychométrie 0632

ABSTRACT

New programming languages are available in the market place that ease the design of intelligent tasks executed by the computer. PROLOG is one of the leading programming languages of this kind that allows programs which result from precise observation of experts and that learn from experience. In order to test the impact of Artificial Intelligence and the use of PROLOG, twenty students were trained to use this language, and were compared with twenty other students in a high school. The students learned how to build an expert system using PROLOG. The hypothesis was that these students would develop abilities to find relationships between concepts and therefore develop some problem solving abilities. Two tests each divided into three subtests were used to measure the ability to find analogies between ideas, to find relationships between visual concepts and to use logical thinking. The results showed that there was no significant relationship between designing an expert system using PROLOG and finding relationships between concepts despite the fact that PROLOG is based on the logic of predicates and that predicates are the relations which link the different characteristics of an object.

TABLE OF CONTENTS

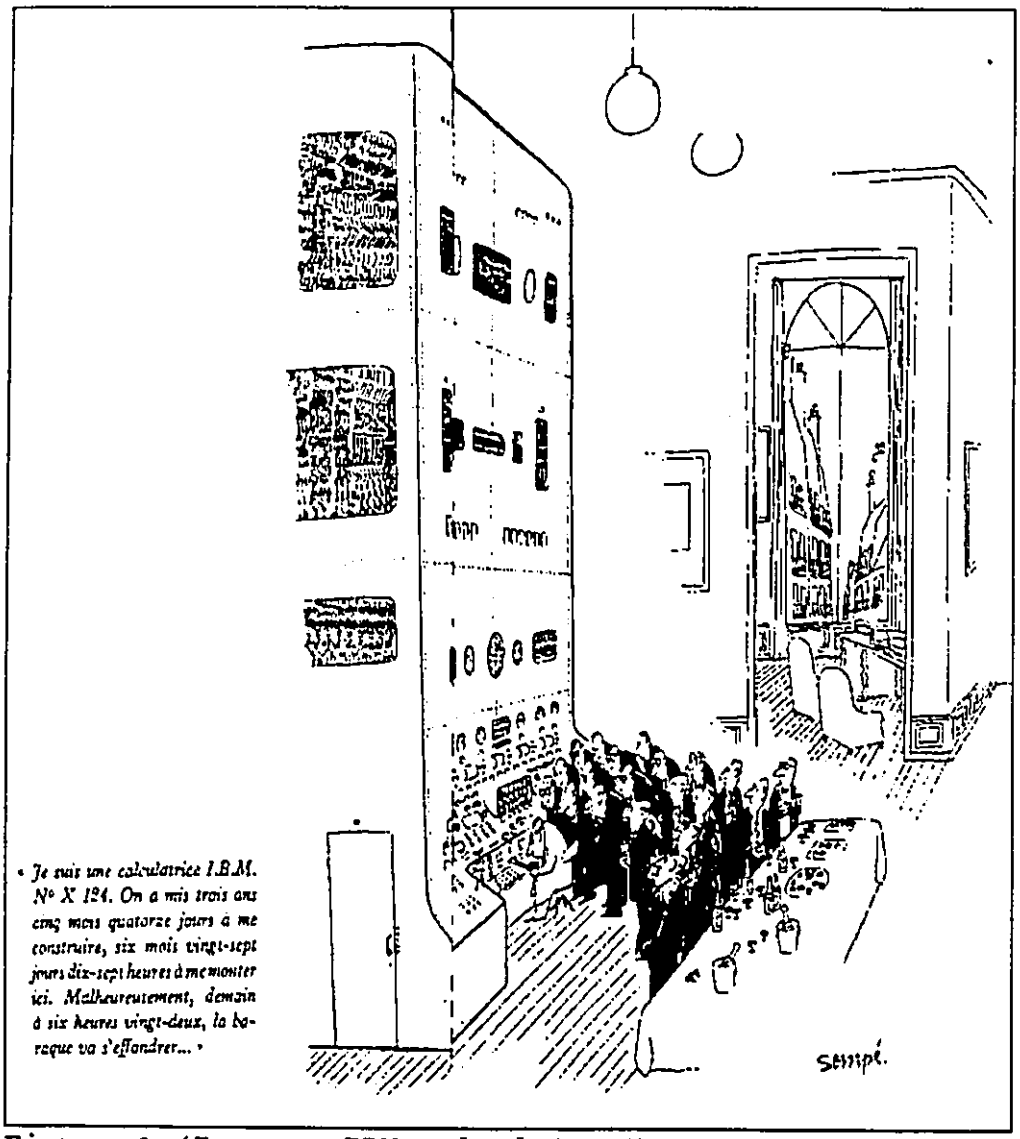


Figure 1:(I am an IBM calculator No X124. It took three years, five months, fourteen days to build me, six months, twenty-seven days, seventeen hours to install me here. Unfortunately, tomorrow at 6: 22 this building is going to collapse ...)

Chapter I

INTRODUCTION

A. General Statement of the Problem

Until recently, computers excelled only in repetitive tasks. Today the technology of the information age allows individuals to teach computers how to think and process data for a specific problem. By transferring knowledge into the computer, human beings can build expert systems in order to help them to make decisions. Artificial Intelligence has brought new tools to help in this task. These tools are capable of making decisions based on a very large amount of data that would require too much time for humans to study. DENDRAL in 1967 was one of the first famous expert systems designed for chemistry in the United States, followed by MYCIN in 1976 for blood control and PROSPECTOR in 1979 for geology(Luger & Stubblefield, 1990). According to Quibel (1989) the American market for Artificial Intelligence tools is worth one billion dollars and is expected to double by 1995. At least 10% of small businesses and most of the largest

companies in the world are expected to acquire tools which will make artificial intelligent decisions. They already look for skilled staff in the area of Artificial Intelligence (Mares, 1992). Hence, teaching elements of Artificial Intelligence at the high school level makes sense if one wants to prepare students for the working world. To develop expert systems or any system to control knowledge is going to become a necessity at school. This will not be a task reserved for advanced students. All students starting from Grade 4 should receive some kind of instruction on AI (Tamashiro & Bechtelheimer, 1991).

The goal of this research is to study the effect of teaching PROLOG, a language that eases the design of expert systems, on students at the High School level. More specifically the research looks at the impact of learning PROLOG and its capabilities to find relationships and solve problems.

B. Definition of the Terms

Artificial Intelligence(AI).

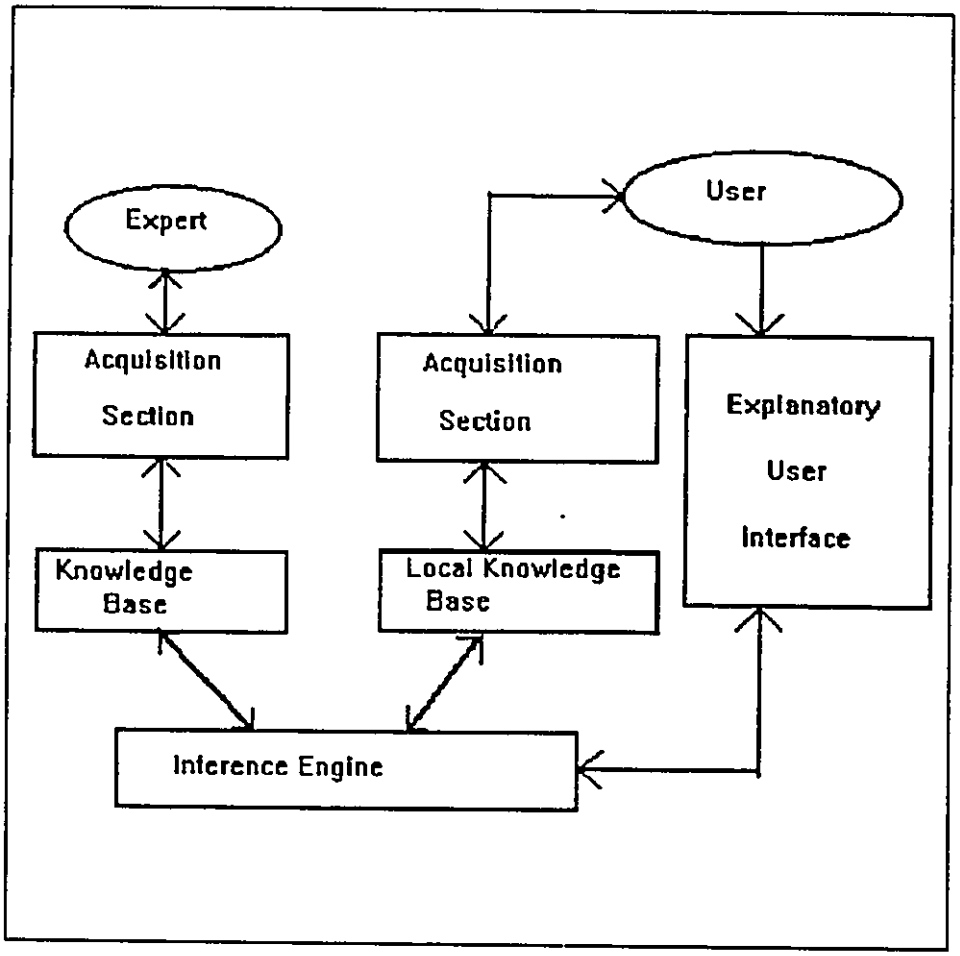
Artificial Intelligence is a computer science term to describe when a computer is asked to execute some

principles of reasoning which give humans the impression that the machine is intelligent and can think in some way.

Expert systems.

An expert system is a piece of software created with a Expert System Generator or by programming with computer languages. It contains a certain amount of expertise that a specialist in the area of the system entered by defining specific rules and teaching facts. This program is used by non-experts to help them to make choices. Such systems not only process knowledge but they can learn from experience. Figure 1 shows the "inference engine". An inference engine uses the knowledge previously entered by the expert but also uses the knowledge resulting from the use of the expert system. This allows programs to learn from experience. It memorizes the results of decisions made and whether or not they are correct. This enriches the bank of knowledge available as references to make decisions without writing a new program or modify it.

Figure 1 : Structure of an expert system.



Definition of intelligence.

The introduction of AI at school goes beyond the teaching of activities using a computer. Hofstadter in Gödel, Escher, Bach: An Eternal Golden Braid(1980), shows how AI brought a new dimension to the world. As soon as humans started to build machines which tried to behave like humans, current ignorance of human behaviour became evident. Around 1950, when mechanized intelligence seemed to reach a noticeable point, the problem became how to define what intelligence was. For Hofstadter, it is a set of abilities :

- to respond to situations very flexibly;
- to take advantage of fortuitous circumstances;
- to make sense out of ambiguous or contradictory messages;
- to recognize the relative importance of different elements of a situation;
- to find similarities between situations despite differences which may separate them;
- to draw distinctions between situations despite similarities which may link them;
- to synthesize new concepts by taking old

concepts and putting them together in new ways;

- to come up with ideas which are novel.

Students working on an AI project are students who try to program intelligent behaviour. Such programming shows two antagonistic views of the problem, which are to think that a computer can have the behaviours listed above or that humans think by following a set of instructions. Hofstadter thinks that computers can follow rules which control other rules themselves following other rules and so on. Therefore, a computer can closely approximate human behaviour and hide the breach between animate and inanimate, formal and informal and flexible and inflexible.

Baron (1988) defines intelligence in terms of abilities: "...those general abilities that help people to achieve their goals, whatever those goals may be, in any real environment". Consequently, teaching how to build expert systems at school involves the awareness of students about their own intelligence and goals they set because they need this awareness to define rules that the computer needs in order to replicate the behaviour. They will also have to look at the extent of

their own knowledge and expertise. This is a process of metacognition where the knowledge relative to a subject does not become known without understanding. Once the knowledge is entered and the expert system is in operation, unexpected problems can appear. The most common is the problem of trust in the system (Yazdani & Narayanan, 1984). Humans can appreciate how to build such a system but they have to accept its solutions even when they cannot understand how the conclusions are reached. Since humans teach the computer, are they doing it right? Are they forgetting any important facts? Can operators trust the system, can they trust themselves? This suggests that the researcher should closely look at the relationships between the students and the computer. Students have to become familiar with the computer and its reactions. They have to be convinced that the computer will only behave according to the rules that they enter. This problem of trust disappears when students gradually build their expert system and can check the effect of the newest rules on the system. Since this research is concerned with relationships between concepts, the instructor must make sure that students are not guessing when finding a

solution. Therefore students have to use metacognitive strategies and look for evidence whenever they try to solve a problem, in order to minimize the doubts.

In order to build the bridge between the concept of intelligence in psychology and intelligence in AI and to understand what one can expect from a computer, Sloman (1984) compares briefly humans and computer mechanisms. For humans, Sloman gives the following characteristics:

- Humans deal with variety, complexity, unpredictability which leads to many constraints.
- Humans are complex systems in order to control all the moving parts of the body and the thinking.
- People have also, a fragile body with changing needs.
- Humans need to be part of a social system which requires them to acquire specific knowledge: Language, social concepts and behaviour related to others.
- "The need to be able to cope with relatively helpless young". Humans have to teach the children "motive-generators" concepts in order to perpetuate human evolution.

> _ Humans have the need to be able to deal with changing goals, principles, and likes. To do this they need to be able to make decisions, and solve problems (p. 178).

By comparison computers have different characteristics for its mechanism. Sloman (1984) writes :

> _ Its memory can contain a very large number of totally different symbols and therefore different states.
>
> _ The symbols in memory can be stored, searched, altered in large quantities.
>
> _ Symbols interpreted as instructions control the behaviours. The computer can control its own behaviour, because instructions can be conditional and react depending on the environment. If beliefs can be represented as symbols, computers can respond to a wide variety of stimuli. Also because of conditional instructions, the system can be goal-directed.
>
> _ Instructions can be compared, evaluated, asserted or rejected in the light of higher level goals. Or, goals can be subdivided into sub-goals (p. 177).

Despite the fact that both humans and computers have a lot of common characteristics there are things that computers can do and that humans cannot and vice versa. Possibly this is because there are still mysterious functions in the brain. Today it is still difficult to write that computers are intelligent in the common sense of the term. In other words, some computers are capable of some demonstration of intelligence(Andrew, 1990).

Thinking.

With the introduction of any reflection on AI, it is necessary to present different types of thinking in order to show the phenomena basically involved. It also helps to understand what the designers of expert systems look for when they try to reproduce behaviour. Also, the knowledge of the thinking process is very important for teaching, because it helps the teacher to prepare the lessons more efficiently (Woolfolk, 1990). In general, thinking refers to a process activated when people are in doubt of something(Baron, 1988). They want to achieve goals and therefore they think about decisions, beliefs and about the goals themselves. This is what Baron calls search-inference framework

knowledge. Humans have a natural tendency to look for good thinking and this influences decisions they make. In fact, when people think they search and infer knowledge. Consequently, if people want to program a computer to make decisions, a way to do this is to help it think in a similar way to humans, considering that they are aware of the way they think, search and infer.

First, humans search for possibilities or possible answers to a problem. The possibilities can come from memory or from external sources like another person or the environment. Second, they also search for goals which are the criteria by which they evaluate the possibilities. Finally, humans search for evidence which consists of any object that helps humans determine the extent to which a possibility achieves some goal. In addition, the process of inference uses the result of the searches. Baron (1988) stated "Thinking is, in its most general sense, a method of choosing among potential possibilities, that is, possible actions, beliefs, or personal goals" (p. 6).

There are three models of thinking. The first one is the descriptive model which refers to common thinking. This is the case when people make a decision

by following their personal method or the use of personal heuristic. An example of heuristic is to consider that people must understand perfectly a problem before they even try to solve it. Even if this statement makes sense to most people, nothing proves that this is logically necessary(Conlon,1991). This model of thinking is especially interesting in AI when designing an expert system. The computer has to be programmed with this kind of reasoning which is a difficult task because of the lack of a logical basis.

The second model is prescriptive and refers to how people should think. For example, this is what happens in the classroom when a teacher implies in a lesson how students should think in a given situation. To write and use specific styles or vocabulary reinforces prescriptive thinking. Students must form letters in a specific way or learn how to behave in a classroom according to specific rules.

Finally, prescriptive models of thinking are those that tend toward normative models of thinking. These models use probabilities and help find the best solutions. People use these different models in different situations but always in the direction of the

right decision.

Logic.

Logic is traditionally described as a normative way of thinking. It is a way of reasoning correctly, or without making mistakes, to solve problems. A logical problem involves a conclusion based on premises. These premises are evaluated as valid or invalid and the conclusion can be then evaluated. For example if one has the following rules :

An X is a Y

A Y is a Z

Conclusion An X is a Z.

If X is replaced by "shepherd", Y by "dog", and Z by "animal", the conclusion is true. But if X equals "men", Y equals "teacher" and Z equals "woman", the conclusion is logically right, but invalid. This reasoning is a syllogism(Lercher, 1985). In other words, logic is a normative model of inference, reached by reflection about arguments(Baron, 1988).

There are different logics depending on the structure of the premises or systems of rules. Propositional logic refers to premises which include

the terms "if", "and", "or", "not". The system of categorical logic is concerned with membership and includes terms like "all", "some", "none", "not" and "no". The system of predicate logic includes the propositional and categorical logic. PROLOG, the language used for this research, is based on this system. A sentence like "The dress is red" is a one place predicate. A sentence like "John goes to school" is a two place predicate because the verb puts two things in relation. In PROLOG these sentences can be written: *dress(red)* and *go(john, school) for example*(Crookes, 1988). When the students have to find relationships between concepts while they design their expert system, the formulation of predicates is the way to express the relationships that they consider important to solve the problem they are working on. The choice of these predicates is responsible for the whole articulation of the expert system and therefore is of the upmost importance.

Logic Programming.

Logic Programming refers to programming computers to do logic as defined previously. It was developed at the University of Edinburgh, Scotland and at the

University of Marseilles, France in the 1970's. The characteristic principles used are the inference of knowledge and the possibility to backtrack during a search for a solution. LISP and PROLOG are the best known programming languages of this type. These use logic to solve problems. PROLOG by its structure can allow instructions in a syntax which can be close to the natural language.

Problem Solving.

Part of the teaching associated with this research consists of presenting techniques students use when solving problems. Students have to deconstruct the process of how problems are solved. It is a metacognitive approach that helps the student to understand the steps involved in the resolution of the problem. Consequently it clarifies the way to program the computer's intelligent behaviour.

Problem solving is utilized to achieve a goal provided by the investigator(Baron, 1988). To solve a problem is to search in a problem space. This happens when one has to reach a goal that one does not know how to reach immediately. The first way to solve it is to try a possible solution. If it fails, one tries another

strategy until the right one is reached. This is the trial and error system. It is mostly used by animals. Thorndike cited in Baron (1988) explained that in this system, behaviours associated with attempts leading to failure, disappear while those associated with success are reinforced. This method is used by humans when no investigation is possible. Thorndike supports the idea that such a way of solving a problem is never really blind. Baron suggests that in fact an unconscious search is made in the memory. The search is very fast and a lot of backtracking is done. It is a work of association between the goal to be reached represented by a symbol or an idea and elements of memory. In the case of recognition, the search for evidence occurs with minimal effort. Recognition happens when identity is found with the goal. It also happens when the goal provokes the recall of a similar structure in the memory. For example the recall of a mental model like the abstract structure constituted of a back and four feet, while looking at an object like an armchair. Inversely, the elements of a problem could also be the parts of a model. A process of pattern matching on the knowledge is done and a corresponding solution is

found. This is called analogical thinking (Copi, 1961).

A second way to solve problems is called "Hill climbing". This happens when one has a way of evaluating whether, at each step of the search, if one is headed in the right direction or not. For example, this is used when the goal, in Chemistry, is to find the saturation point of a substance or when one wants to find the correct dosage of a medication. One tries a certain quantity and looks at the results.

A more sophisticated method is used when at each step one can evaluate how far away one is from reaching the goal. This is the means-end analysis. This is what happens when one writes a program on a computer and tests it. People usually can see how far they are from the goals they want to reach and they act in that direction. Resolving equations in mathematics implies very often a means-ends analysis. One writes equivalent propositions until one finds a simple enough expression to give the answer.

AI uses these techniques. It also uses subgoals when executing a search for an optimal path (Cohen & Feigenbaum, 1982). The goals one reaches are subdivided into different stages to reach their optimal path.

These subgoals are themselves decomposed in subgoals and so on until the objectives are found. This working backward approach is based on the assumption that the best solution to a problem passes by the best solution of each of the subgoals. PROLOG is known for being very effective to solve problems with this method because of its capabilities to deal with recursive tasks which are to find the best way to reach each subgoal until the final goal. The "Search for a route" problem(See Figures 3 & 4) is a good illustration for this method of resolution. The goal is to go from one country to the other using the fastest way. The givens are the borders between the countries that one can read on a map(See Figure 3). They are translated into the predicate "Borders" (See Figure 4). In fact the program starts from the last line of instruction where the program tries to find a country C3 that has a border with C2 and that has never been used before. Then the same thing is done but C3 becomes the new C2 until C1 is reached. In other words, one has to find a first subgoal to reach the country which is the closest to the final goal C1. At this point one has to find a new subgoal which is the closest point to the first subgoal

and so on until complete resolution(Crookes, 1988; Nedzela, 1990; Luger & Stubblefield, 1989). This type of problem suits perfectly a programming language like PROLOG. To simulate this type of resolution of problems, programming languages like PROLOG are more efficient and easier to use to solve problems than others(Crookes, 1988 & Bratko, 1988). When solving a problem, the human brain has an automatic tendency to try different possibilities when a failure occurs. The human mind is capable of an automatic backtrack in the attempts to succeed until the final goal is reached (Simon, 1969). With languages based on the logic of predicates, this backtracking process is part of the language itself. When a country does not suit the goal another solution is tried until all the possibilities are exhausted.

Figure 3: A map of Europe to define the borders.(Crookes, 1988)

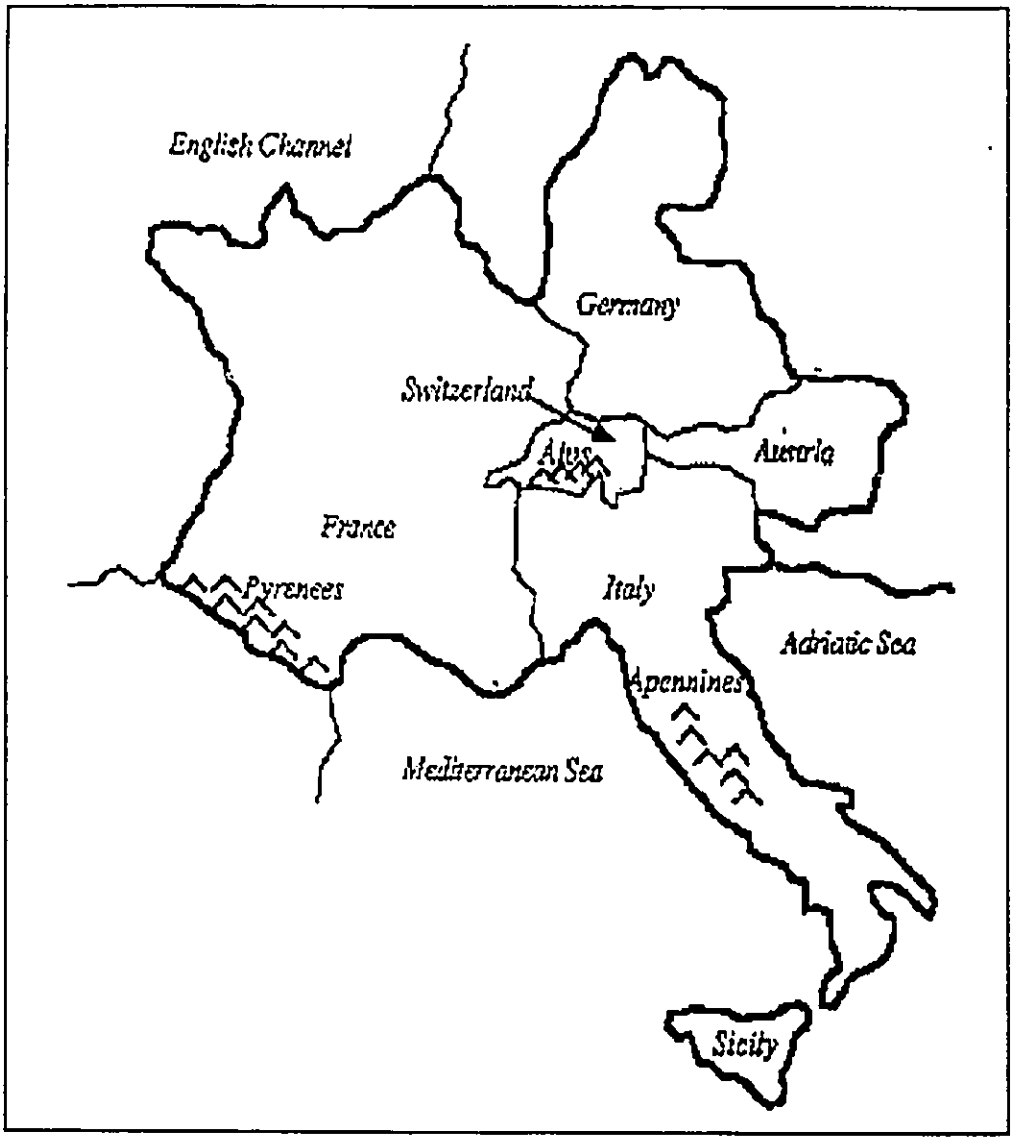


Figure 4: Subgoals and recursivity. (Program written by Crookes(1988)

```
Borders(france,germany).
Borders(france,switzerland).
Borders(france,italy).
Borders(germany, france).
Borders(germany,switzerland).
Borders(germany, austria).
Borders(switzerland, germany).
Borders(switzerland, france).
....


safe_route(C1, C12, [C1|, _).
Safe_route(C1, C2, [C3 | R], So_far) :-
                borders(C1,C2),
                not (contains (So_far, C3)),
                Safe_route(C3,C2,R,[C3| So-far]).


{This predicate, when evaluated, would return all the
routes between C1 and C2. Route is a variable
containing the list of countries in the path. So-far
contains the list of countries already tried}
```

Part of the challenge in the programming of an expert system is in the formulation of heuristics. People use heuristics when no particular method of resolution seems applicable. This is reasoning that only applies to the environment of the problem to be solved or to similar problems. People learn from experience. They learn to separate the variables from the given when solving an equation in mathematics. Using heuristics methods implies that people ask themselves whether they have ever met a similar problem in order to apply the heuristics developed previously. This is frequently used at school. Teachers give a prescriptive way of thinking and teach heuristics to students for them to apply in similar problems. When programmers design expert systems, they enter heuristics in the computer in the form of tests, and the operations are executed under certain conditions. The broader the tests the more powerful are the heuristics because it can therefore be used in a wide variety of situations.

Heuristics can be seen as an alternative to logic. It can solve problems when logic does not suit the

problem and no logical rules can apply. However, Andrew (1990) indicates that an heuristic is not something coming from the dark side of the brain but rather an analogical reasoning based on the appropriate association of actions and situations.

Chapter II

REVIEW OF LITERATURE

A. Introduction

Today's society operates a knowledge-based economy, in which people are increasingly dependent on technology for growth and effective international competitiveness. Effective learning, information management and skilled intelligence are today's raw materials (Farrell, 1991; Yates & Moursund, 1989). Part of the educational challenge is to develop a Canadian workforce that will have the skill, adaptability and motivation to prosper. Technology requires and gives at the same time, the opportunity to optimize many aspects of education (Hathaway, 1990). Repetitive tasks which were handled previously by humans in factories are disappearing. These tasks are now completed by robots and other repetitive machines. Nowadays workers have to solve problems and make decisions which require that they are experts in different areas. They have to deal with so much knowledge that they have to learn how to organize it in the most efficient way.

B. Experiments.

Most of the experiments using PROLOG in Education

have been done in Great Britain. The Prolog Educational Group in Scotland organizes yearly international meetings gathering researchers and educators(Conlon, 1991). Other experiments have been tried in Ontario at the Centre for the Study of Computers in Education. Wideman and Owston from York University (1988) required students to classify different types of living matter and define some production rules. They worked with thirty-seven grade seven students over a three month period. The students had access to an IBM 4131 and used an IBM expert system. The teacher taught the students how to classify animals using rules. The logic was based on "if ... then.." rules. For example a rule might be:

If legs is 'four' and face is 'whiskers' then animal is 'cat'.

The parameters were introduced by giving a name and constraints. For example, SHAPE was defined as taken from('triangle', 'square', 'pentagon'). The teachers' and researchers' roles were to promote the students' own discovery of classification rules and employment of problem solving strategies in building their systems. The students worked in groups of two and

three. First students had to develop charts showing the classification of classes, orders and species according to key criteria, then to define the parameters with the constraints and finally to write the formal rules for their expert system. The students were tested twice, before and after the teaching. The teachers took detailed notes of the classroom interactions and activities. Other data were collected using informal interviews. The teachers were questioned regarding the outcome of student project development. The results showed that all the students managed to build an expert system although they encountered various difficulties and needed assistance. More especially the researcher explains that students had problems with integrating the various levels of classification which gives the articulation of the expert system. Novice problem solvers in the control group behaved the same way as the experimental group when solving problems. The researchers noticed that both groups had cognitive and metacognitive deficiencies in their responses. They had a lack of goal-related planning, a lack of interconnectedness of output, and no sustained effort was made to find out what the text of the problems were

trying to say. Finally , inferential thinking was restricted, and little hypothesis testing was developed. They noticed that the evidence of skill gained is not always found. The first reason identified came from the observation that problem solving skills learned in one domain were not automatically transferred to another as Baron(1988) previously stated in other circumstances. Also the language used mandates that the students spend time in debugging programs and focus on problems of syntax. The researchers criticized the fact that the students had to use an Expert System shell which did not give them an opportunity to develop their own original problems because they had to follow specific structure and organization. This showed the importance of the way the operator communicates with the system and its trust in it.

The choice of PROLOG in this study is motivated by the fact that its syntax is simple and people do not need to be good programmers to produce noticeable applications(Bratko, 1988). Moreover it reduces some of the problems met by Wideman and Owston in their research. The use of predicates to enter facts in the computer should simplify the passage between data

representation on a chart(with arcs, nodes ...) to data to be computed, because as presented earlier, there is a resemblance between predicate and data structure in the brain. Two problems emerged from this. The first is the necessity to have a method to extract knowledge from the expert. In this case, the students have to make some kind of introspection of themselves. Working in groups and having students question each other should facilitate this. The second problem is how to represent the data. Different possible diagrams showing the relationship between concepts have to be presented and discussed. An explanation for the failure of the research of Wideman and Owston is that the students have problems with the design of a diagram tree in order to organize the data.

Bloom and Broder(1950) showed that many of those higher-level skills can be taught to the vast majority of the students (Chance, 1989). Even though teachers are using techniques for problem solving, they are not aware of their existence. Students have to be aware of metacognitive techniques to solve problems and they must employ these strategies as often as possible. They have to use means-ends analysis instead of blind

search. Another frequent attitude is to avoid problems instead of trying to solve them. For many students, avoiding a problem is giving up mentally, even before they physically decide to do something(Bransford & Stein, 1984). Bailin(1991) in researching creativity, writes that critical thinking is associated with learning academic disciplines in more than a superficial and rote manner, where individuals learn how to weigh the consequences of actions. Observing, drawing inferences, generalizing, conceiving alternatives, detecting standard problems, and realizing appropriate actions are different steps to pursue(Ennis, 1987). These last actions are grouped under the term "Intelligent Criticism" by Bransford and Stein (1984). The design of expert systems involves each of these actions at different steps of the conception.

Another research study conducted by Knox-Quinn(1988) with 27 students in a junior high school, working with an expert system generator shows that the design of an expert system is an important new technique for teachers across a wide range of subjects. It can help students to analyze and encode their own

decision-making process, becoming more aware of the factor upon which they make everyday decisions. Knox-Quinn thinks that the design of expert system can be used as an instructional strategy with a variety of goals including increasing higher order thinking and evaluating student's cognitive map.

Conclusion

What emerges from this review of literature is that attention must be on:

- The awareness of the students that they are learning specific strategies of problem resolution.
- The certainty that students are using inferential thinking and hypothesis testing to solve problem in their activities and when writing the research test.
- The reduction of frustration caused by the use of the software in order to reduce bias in the measurement.

Chapter III

RESEARCH DESIGN

A. Research Questions and Hypotheses

It is hypothesized that the use of Artificial Intelligence tools can be beneficial for students when solving problems. More specifically, it is expected that students who develop expert systems using the PROLOG languages will develop abilities in their efforts to find relationships between concepts. This will be evident in solving problems in verbal analogies, visual problems, and worded problems using logic. It is reasonable to expect the same results with logic programming tools. It is expected that the results will be the same for most of the students regardless of their abilities.

B. Significance of the Study

Artificial Intelligence is a new area in Education. New software is available on the market. Tools created with languages like PROLOG allow experts to make decisions even when they are dealing with a large amount of data. In secondary schools, students have to learn how to deal with the same problems of decision making. This study looks at the way it affects

the students positively. This research points to the need to spend time on the analysis of problems in Computer Science classes and especially on how really efficient the activity of building an expert system using PROLOG might be. The research conducted by Wideman and Owston(1988) looks at the general behaviour of children while solving problems. The researchers look at the behavioral effect in a more specific area: The ability to find relationships which is very important when solving problems. Therefore this research helps to clarify the impact of AI tools on the students cognition and consequently their usefulness in their development.

C. Subjects

The research was conducted at l'Essor Secondary School, a French high school from the Essex Separate County Board of Education in Southern Ontario. About 50 students taking computer courses at the general and advanced level in Grade 11 and 12 served as a subject pool for the research. Although the courses in which the research took place were labelled as advanced, the students had a variety of intellectual abilities as well as different learning styles and levels of

motivation. They also came from different social environments.

Some of the students in Grade 11 had no experience with computers. Others took a typing course in Grade 9 or had a personal computer at home. Others had learned elements of programming and could design simple programs without any directives. None of the students in Grade 11 had received any instruction on methodologies concerning the design of computer programs. However some of them had some basic programming experience. Students in Grade 12 can usually work on a computer project with a minimum of direction since most of them had already been immersed into the programming methods in the past years. The age of the students ranged from fifteen to eighteen.

D. Instrumentation

A test of cognitive skills was necessary to assess the students aptitude on certain cognitive abilities(Troy, 1985). Since classification and search for relations between objects are key problems in AI, the researcher designed two parallel tests to serve as pretest and posttest(see Appendix III). Each test contained three different kinds of exercises. The first

kind involved analogical reasoning. The task consisted of analyzing the meaning of 2 words, finding some relationship between them and in expressing the same kind of relationship on two other words using suggested possibilities. Thirty-five relations have to be studied in each test. This type of test is used by many universities in English-speaking countries like the United States, Australia, England and Canada. As it does not exist in French and the population to be studied is francophone, the researcher translated and adapted some exercises. In order to avoid any vocabulary problems that are not part of the test, the exercises selected were chosen for the simplicity of the terms they used or because of their similarity with English words. The first variable measured with this test is the ability to see relationships between concepts (Bader, But & Steinberg, 1988).

The second kind of exercise involved logical reasoning. The task is composed of worded exercises. What is measured in these exercises is the ability to use logic to solve problems. For example students have to classify series of names of things according to specific rules such as size or characteristics. The

solutions are found with a careful study of the relationships between the elements to be classified.

The last exercise includes a variety of visual tests that measure the student's ability to find arithmetic relationships between figures and apply them to other figures. These are sets of figures like cards or dominos linked by different relationships. For example, three cards are proposed together and linked by a specific relationship like the sum of their value. The student has to link the following set of cards using the same relationship. These tests measure the student's ability to solve visual reasoning problems using logic.

With these exercises, the researcher intended to build short portraits of the student's cognitive capability and to look for different kinds of relationships when solving problems.

Two sets of tests used in the research have been designed by the researcher. One half of the students wrote one test first while the other students wrote the alternate form first. This served to counterbalance for differences in the two tests.

E. Procedure

Two groups of students were tested. There were twenty students of Grade 11 and 12 advanced that were instructed. This is the experimental group. The second group, a class of twenty students of Grade 11 was tested at the same time but they did not receive any instruction. This is the control group. Both groups were tested twice. The first test occurred before any work was done on AI. A unit on AI was then taught to the experimental group.

The courses at l'Essor Secondary School are semestrial. Each class lasts eighty minutes everyday during about eighteen weeks considering the interruptions for different activities. Therefore the unit could not last more than three to four consecutive weeks in order not to affect the program of each class.

Immediately after the unit was taught, the students were tested once again under the same conditions using similar exercises.

The researcher acted as a tutor and as a facilitator in order to help each team of one or two students use PROLOG in the most efficient way possible. Teaching of theory was reduced to its minimum. In the

experimental group, the content of the lesson was more thorough for the Grade 12 students than for the Grade 11 students. Before students worked on computers they were trained to draw organizational trees in order to help them clarify their thoughts(Bratko, 1988). Other design suggestions proposed by students were accepted. They also had to define their goals for their expert systems. Depending on the classes that were taught, expectations were different in terms of level of sophistication of the expert systems.

In general, an expert system consists of two parts: First, a bank of knowledge reflecting all the concepts necessary in the area studied, in the form of predicates. Second, a bank of clauses or relations between predicates that are used to interrogate the information system. For example, if the student were to develop a system on mechanical issues, the system should be a tool to help in an effective investigation of an engine problem. When the system is sophisticated enough to answer the target questions that the students had previously selected with the help of the teacher(the final goals), the task is considered then to be complete.

F. Teaching activities.

At the beginning the students were taught about metacognition. With a series of games, they had to understand how they make their decisions. The first game studied was Tic-Tac-Toe. The students had to write down their strategies. Some explained how they tried to get the corners, others always played the middle. The objective was to push the students to take control of their own thoughts and to try to look at any problems in terms of processed data. A few problems related with the search for a path were studied. These problems, frequently studied in Operational Research help students to discover some of the difficulties in data processing. The main difficulty is the total understanding of the problem. A close reading of the given problem is an absolute necessity. Then came the problem of the expression of the goals of the problem. At this point the students showed some difficulties. The students were confused with the language. Since most of them studied in French at school and speak English at home, it could have been logical to think that the expression of the problem in natural language was more difficult. But as one student mentioned it, it

was almost an asset, because they previously had to really clarify their thoughts before building any sentence. In other words, to speak in French instead of English might have helped the students to push them to think about what they think.

The next step was to produce any kind of representation that could help in manipulating the data. This could be a chart or drawings showing the relations between different objects. For example, a problem involving three missionaries and three cannibals who had to cross a river using a canoe was suggested. Some students started to draw on different blackboards the elements involved in the problem. They did not take long to understand that sophisticated representations were useless and that only a few characteristics were necessary. A "C" for a cannibal, an "M" for missionaries and a "B" for the boat were among the solutions found. The second step consisted in defining subgoals by answering the question: "What do I have to do in order to reach the final goal". The students found naturally a sequence of subgoals, but the important aspect was in the fact that they had to write them down. These lead to the discovery of the

process of "backtracking" which is a strong notion in PROLOG. When the students could see that they went in the wrong direction and that they had to return to previous steps it was time to make them aware of their own automatic way to backtrack in their thoughts.

These activities were important for motivating the students. Even though the students knew where they were going, they did not know exactly what would happen. Also, the term "artificial intelligence" had to be restored to its real meaning. It seems that students tend to associate these words with some kind of "magical" device. Although, during the first class the teacher gave an explanation of the meaning of intelligence, some students had difficulty understanding the meaning of AI. The first group of activities that lasted over ten days, helped in that direction. A quick study of the notion of "predicate" and its place in a knowledge system gave a natural connection to the PROLOG language. This was easily done by asking the students why they call the object in front of them "a chair". The natural answer is that it has four feet and a back. This leads to the predicate "is-a(chair, 4legs, back)". The next step is then to

introduce the students, naturally, to the syntax of PROLOG. The first exercises consisted in translating from natural language to the syntax of PROLOG. To keep the motivation up, some sentences like "Joe eats Paul" (where Joe and Paul are actual students of the group) were translated in PROLOG as well as all kinds of sentences. This showed the freedom possible in the use of the language and to reassure the students that PROLOG can be a user friendly language. It is important to notice that too many times Computer Science is associated with mathematics. In other words, one has to be good in mathematics to do well in Computer Science. Therefore, it is very important that the students feel that they are capable of handling the situation. Then all the exercises suggested in the first chapters of Bratko's Prolog manual(1989) can be executed with a minimum of difficulties.

Despite the fact that less support was provided to the grade 12 experimental class, students were capable of producing programs on average more sophisticated than students of Grade 11. According to the results of the academic tests submitted in class Grade 11 students did not seem to show more difficulties in the

understanding of the concepts taught. Nonetheless some students in Grade 12 had some problems with the construction of programs because they were confused with concepts they used when they learned traditional languages.

The students had to build two projects. The first one concerned a classification that they were using in other courses. An example of a classification was given to them as a starting point. They then had to implement the same kind of reasoning in another subject. Some students classified hockey players, others cars or goods from a store. It took two to three hours for the students to build a classification and to prepare a list of different possible questions to ask the knowledge base.

The second project was more sophisticated. The subject was to design an expert system that could give the exam schedule at the end of semester. This included the interview with the vice-principal of the school who is in charge of this task. M. Godin was then invited as the expert. He explained how the schedule is designed. A lesson on the design of expert system was taught using the suggestions from Hart(1986) concerning

the specificities associated with the design of expert systems. They were taught how to analyze the sentences of the expert as given for an information system and to search for relationships between data. The students were asked to produce a document that sums up all the decisions made and their causes when designing the schedule(Hart, 1986). Since the Vice-Principal was a former teacher, the problem was presented with a maximum of clarity. However, some students asked some specific questions that raised possible difficulties that had never occurred. The fact that the students were working on a program that was going to be used by the school helped the students to keep a high level of motivation. Each student built one program while working with the help of a peer. Some students never had the time to finish their program. Finally, the students chose the program to be given to the Vice-Principal. In order to simplify the task some students chose to build a tool to help design the schedule. Others, designed a system which gives all the possible schedules for the exams of the term. In the case of the simple version of the program, the user had to enter the number of the course and the day for the exam among

five possible days. The program then checks any conflict of students taking two exams the same day. It also suggests a possible date for it. This last project required a lot of knowledge of the programming language. For example the use of list of objects had to be taught. This has been done using an example presented with an overhead projector. A minimum amount of theory had been taught and all the elements necessary were given as soon as possible in order to limit any frustration.

Finally, the second test was submitted to the students as soon as the second project was done. The data generated are presented in the next chapter.

Chapter IV

PRESENTATION OF DATA

A. Results To ensure appropriate counterbalancing for the two test forms, equal numbers of students in the experimental and control groups were selected such that the same number of students were tested using test-form one first as test-form two first. Missing data and these counterbalancing constraints reduced the sample size to 20 students for statistical analysis. The data for the three reasoning tasks were then analyzed by means of two-way analyses of variance (ANOVA) using Group (experimental, control) and Test (pretest, posttest) as the independent variables with the Test variable treated as a repeated measure.

B. Analogical Reasoning

For the analogical reasoning task a two-way ANOVA was computed on the raw test scores. There were no main effects for Group, $F(1, 18) = 1.71$, $p > .1$, or Test, $F(1, 18) = 0.23$, $p > .1$. Nor was the Group by Test interaction significant, $F(1, 18) = 2.64$, $p > .1$. Means and standard deviations are reported in Table 1.

C. Logical Reasoning

For the logical reasoning task a two-way ANOVA was

computed on test scores. Again, there were no main effects for Group, $F(1, 18) = 0.02$; $p > .1$, or Test, $F(1, 18) = 0.64$, $p > .1$; nor was the Group by Test interaction significant, $F(1, 18) = 0.31$, $p > .1$. Means and standard deviations are reported in Table 2.

D. Visual Reasoning

For the visual reasoning task a two-way ANOVA was computed on the test scores. Again, there were no main effects for Group, $F(1, 18) = 0.74$, $p > .1$, or Test, $F(1, 18) = 0.10$, $p > .1$; the Group by Test interaction was not significant, $F(1, 18) = 0.42$, $p > .1$. Means and standard deviations are reported in Table 3.

In summary, these findings offer no support for enhanced reasoning for the experimental group as a result of exposure to the PROLOG activities. There were no differences between pretest and posttest scores for any of the three reasoning tasks.

Table 1

Means and Standard Deviations for the Experimental Group and the Analogy Reasoning Test

Group		Experimental	Control
Pretest	M	19.20	16.20
	SD	2.04	4.02
Posttest	M	17.90	18.60
	SD	2.69	3.72

Table 2

Means and Standard Deviations for the Experimental Group and the Logic Reasoning Test

Group		Experimental	Control
Pretest	M	2.70	3.10
	SD	2.31	2.13
Posttest	M	3.80	3.30
	SD	1.23	2.11

Table 3

Means and Standard Deviations for the Experimental Group and the Visual Reasoning Test

Group		Experimental	Control
Pretest	M	10.40	10.20
	SD	5.38	4.13
Posttest	M	10.90	8.70
	SD	4.86	4.17

Chapter V

DISCUSSION

A. Support for the hypotheses

The experiment showed no support for the hypothesis that PROLOG can be beneficial for students when solving problems. Examination of individual scores showed a small increase for some of them while other students remained at the same level. The range of scores was large. Some students scored much lower than others who performed very well.

B. Possible reasons

The same teaching approach was used for all the students and the field dependence of the students was not addressed. Some students could impose their own structure on the problem of the school schedule. While a few students had difficulty focusing on one aspect of the situation. This could have influenced students in their comprehension of the Prolog syntax. Also, it could have hampered the reasoning of some students in their search for a solution acceptable in the Prolog philosophy. This could explain the wide range of the scores.

The sample size was small. Significant differences

may have emerged with a larger sample. The standard deviation was high and consequently the result although slightly higher in the posttest, was not significant.

The lessons were taught over a four month period. Also during this period, a few lessons were interrupted or cancelled for different activities or holidays. This was a short time period in order to measure a variation in the student's ability.

If some operations are facilitated with the Prolog language, others seem to create some confusion for the new Prolog programmers. This is especially true if they have some experience with structure oriented languages. The scores can be largely affected since these problems were not controlled during the teaching session. This is one of the problems that Wideman and Owston(1988) encountered in their experiment.

C. Other observations

According to a questionnaire that the students filled out at the end of the second test, the students expressed the feeling that they had increased their knowledge and their abilities to solve problems and showed some interest in the Artificial Intelligence(See Appendix III: Résolution de Problèmes: Partie II).

Also, the direct observation of students offered valuable information. Despite the fact that Grade 11 students had no or little background in programming they did not experience more difficulties in the use of the PROLOG language than Grade 12 students. In fact Grade 11 students had less difficulties with the syntax of the language because they did not have any prior exposure to structure oriented language.

Finally, in the activities and project done in the class until the end of the semester the majority of students in Grade 12 chose to keep working with PROLOG instead of using TURING which is the programming language they have learned in their previous years. This suggested that students found in Prolog a tool which gives an answer to problems in an easier manner than with other programming languages. This is a success from a teaching point of view.

D. Future directions

The researcher had no control on the number of students in each group. Apparently, findings might have been in favour of the hypothesis if more students would have been tested and the population more homogeneous. Consequently, a further investigation in this area

would require a more accurate testing of the students in order to group them according to their learning styles and abilities. Emphasis should be on metacognitive strategies in order for the students to have total control of their work. This would give more information on ways to teach the PROLOG language and the design of expert systems.

Finally, a suggestion for future research might be to study very specific mental abilities that could be linked to the design of expert systems with PROLOG that can be measured. One example might be the ability to solve certain types of analytical problems. However, it must be kept in mind, as Baron(1988) writes, it seems that no experiment shows that practice on mental activity can improve general mental skills and help to create more automatism, like exercising would develop the body. Neither can rote learning improve the mind. It is only good to develop specific abilities. To practice discriminating "M" from "N" does not help to discriminate "A" from "B".

E. Summary

Prolog is a tool which offers very interesting features if one wants to program sophisticated

applications. With a few simple statements Prolog can process a lot of information. Therefore, students through the experiment deal with problems that require some high-level expertise in programming when using structure oriented languages. The difficulties come from a clear analysis of the problems to solve or rather from a clear analysis of the expert to imitate. Because the experts are often the students themselves, metacognitive techniques and strategies are used inductively. Even though the hypothesis that abilities to find relationships would increase, was not supported, the students in this experiment reached their goals in designing their expert system, which is normally a complicated task. This is a success that needs
further investigation in order to clarify which abilities are enhanced in the process.

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APPENDIX I

Letter for the Research Ethics Committee.

Rivière Frédéric
708 Old Tecumseh Rd.
#RR1 Belle River
NOR 1AO ,Ont.
Tel : (519) 979-9611

Friday December 4, 1992.

To : Research Ethics Committee
Subject : Request for Research Approval

Dear members of the Committee,

The research I intend to do aims to support the idea that the use of Artificial Intelligence (AI) tools develop problem solving abilities for secondary school students. I would like to work with approximately eighty students from Grade 11 and 12 of both sexes.

a) Starting February 1993, I will be teaching Grade 11 and 12 Advanced Computer Science and a Grade 11 Advanced French course. I will include a unit on AI where students will learn how to programme with PROLOG, a logic type of programming language. Students will have to look at logical relationships between objects and concepts.

b) I designed a test to measure the student's ability to find relationships between ideas and a few small problems to solve using logic. It is inspired from the Miller Analogy Test which is used by several universities in Canada and the United States. Students will be tested twice: A pre-test and a post-test. The comparison of the raw scores will give an answer to the research question.

c) The teaching of this unit on AI is compatible with the goals in education as defined by the Ministry. Therefore it will not interfere with the normal instruction of the class. There are no physical or cognitive activities that could be harmful to the students. There is no reference to the ethical origin of the students. Students will work within their own abilities. The research aims to work with students at

different levels.

d) The students can decide whether or not they want to participate in the research. A letter of consent will be sent to the parents who will return it signed. The students will put their name on the tests in order to compare the results between both tests. However, the conclusion will be based on the group results. Nowhere will the score or the name of an individual be referred to. Also, in the instructions for the test, it will be mentionned that it will not be marked and that there is no pass or fail grade. They just have to do their best.

I believe that the research should be fruitful for education as well as for the students who will learn techniques and skills that they will certainly use when entering the work force. I remain available to the committee for more details.

Sincerely,

Frédéric Rivière

APPENDIX II

Letter of consent:

Chers parents, Le 4 janvier 1993

Dans le cadre de recherches sur l'enseignement d'outils en Intelligence Artificielle pour une thèse de maîtrise en éducation, je vous demande d'autoriser votre enfant, si celui-ci le désire, à participer à une étude qui vise à supporter l'hypothèse que l'enseignement du langage de programmation PROLOG, et la réalisation de systèmes experts développent des habiletés pour résoudre des problèmes.

Les élèves seront testés avant et après l'enseignement de cette unité en IA. Il s'agit de tests dans lesquels les étudiants doivent retrouver des relations entre différents concepts. Les scores des élèves ne seront pas considérés individuellement mais en groupes. Il n'y a aucun risque ni physique ni mental pour les élèves. Les scores de chaque individu resteront confidentiels.

Ces recherches s'intégrant dans le programme-cadre d'informatique, n'interfèreront pas avec l'instruction normale du cours.

Comme dans la plupart des recherches, les résultats seront gardés à la disponibilité d'autres chercheurs. Le projet a déjà été approuvé par le Comité d'Ethique des Recherches de Faculté d'Education de l'Université de Windsor (FREC). Cependant si vous aviez des questions à ce sujet, je vous inviterais à prendre contact avec le FREC au numéro suivant : 253-4232, Ext 3800.

Je reste à votre entière disposition pour tous renseignements concernant ces recherches.

Je vous remercie,

Frédéric Rivière
Enseignant

APPENDIX III

The tests.

Even though the title page indicates an order in the test, it is not used in this manner. Both tests, part one and part two were used during the two sessions of testing in order to avoid a problem with the variation of level of difficulty between the two sets.

VITA AUTORIS

NAME	Frédéric Rivière
PLACE OF BIRTH	Tours, France
EDUCATION	University of Tours, France 1981, Certificat Universitaire d'Informatique University of Windsor, Ontario 1990, B.A. 1991, B.Ed. 1994, M.Ed.
PROFESSIONAL EXP.	System Analyst, Microcomputer System Manager in the Software Industry in France between 1981 and 1989 Computer Science teacher at l'Essor Secondary School, St Clair Beach, Ont. since 1991