AN INVESTIGATION INTO THE EFFECTS OF DATABASE USE ON THE ORGANISATION OF STUDENT KNOWLEDGE.

by

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A THESIS
PRESENTED IN PARTIAL FULFILMENT OF
THE REQUIREMENTS OF THE DEGREE OF
MASTER OF PHILOSOPHY
IN
EDUCATION

EDUCATION DEPARTMENT
MASSEY UNIVERSITY

PALMERSTON NORTH, NEW ZEALAND

AUGUST, 1989

ABSTRACT

A knowledge based view of expertise points to the importance of well structured domain specific knowledge in developing expertise in a particular field. This study reports on the way in which a computer based data management system appears to influence student organisation of declarative knowledge of a domain towards more expert-like cognitive structures.

A class of Intermediate School students was divided into two groups. Groups had equal access to computers in terms of time, but one group used a word processor during the class program while students in the other group used a database to assist them in their classwork. For both groups, classroom practice stressed the importance of working in an environment that emphasised use of metacognitive strategies. It was hypothesised that the database group would show significant improvement in terms of the number of chunks, and the depth, of cognitive structure inferred, relative to the word processing group, as a result of their increased ability to discover relationships and trends in the data through datafile manipulation.

Cognitive structures were inferred using two techniques. The main technique (Ordered Tree Technique) inferred cognitive structures from each student's ordering of a set of concepts relating to the class unit of work. Analysis of pre- and post-unit structures inferred from this technique indicates that the database group did in fact develop significantly more expert-like cognitive structures than the word processing group. A second technique (Concept Structuring Analysis Technique), used only post-unit, provides converging evidence that supports this finding.

Results are discussed in terms of the type of restructuring that has occurred, the context in which the results arose, and the validity of depth and chunking as variables relevant to education. It is suggested that further research could focus on explicit knowledge representation by students as a way of helping those students develop their expertise in particular knowledge domains.

ACKNOWLEDGEMENTS

There are several people, and groups, whom I wish to acknowledge for their part in the construction of this thesis. First, and foremost, thanks to Annette for her invaluable support and encouragement from beginning to the very end. To the people in the Thursday morning group, thanks for continually reminding me how important our children are, ensuring I kept a focus on people, not machines. My fellow graduates have provided a breadth of discussion and diversity of opinion that may not be evident in the research reported here, but has certainly influenced my approach to educational computing research and the way I shall conduct it in future.

I've had assistance, that has saved me enormous amounts of time, from Ken Mercer. Ken's wizardry with computers made the task of data entry, data checking and data analysis extremely efficient. His enthusiastic approach to all the problems we met seemed to make finding solutions to them a relatively easy and painless process.

My supervisor, Dr. Ken Ryba, has helped in two ways. He had a way of making me feel good about my work, especially during those times when I felt I wasn't getting anywhere. While this encouragement bolstered my morale, his positive and careful commentary on the many drafts he read has contributed to my conceptual understanding of the area I'd chosen to work in. Many thanks Ken.

Special thanks, of course, to the people who allowed me to become part of their class community for nearly six months - Bobbie Oatway and the students in Room 2. We all seemed to work well together and ended the six months still friends. Their farewell comments would indicate that I gave them as much as they gave me. I hope this is the case.

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CHAPTER ONE

INTRODUCTION AND REVIEW

Computers and the Learning Process

When computers were first considered for use in education the thrust was towards their use as instruction delivery systems, replacing the teaching machine of the 1950's with a more flexible instrument for delivering programmed instructional material. Students were thus learning from computers. This approach continues today as one aspect of computer based education. A second aspect of computer education has focussed on learning with computers. This facet of computer use in education is concerned with the use of computer tools such as word processors and databases, and student programming of computers.

The development of interest in learning with computers came about as a result of attention being placed on learning as a process, and the realisation that computers could be used in a way which focussed on this learning process. Seymour Papert's (1980) work about the use of, and the philosophy behind, the language LOGO, placed emphasis on the importance of "powerful ideas" around which LOGO is based. His work stressed development of heuristics and skills, through programming, which would be applicable to problem solving situations outside the LOGO environment. The possibility that general transfer of problem solving skills was achievable was an exciting claim.

Similarly exciting claims have been made about the use of computer tools. Used as tools to aid cognition, computers provide a means to manipulate symbols of different kinds (representations of number, space and language) (Olson, 1985). The important aspect of tool use is that it may enable people to "..manipulate relationships among elements in symbol systems in ways that are orders of magnitude both faster and qualitatively different from what was possible before." (Hawkins, Mawby & Ghitman, 1987, p.276). This conception of the computer as a means by which students can extend their own learning capabilities is supported, for example, by Shiffman (1986) who describes the computer as a tool for enhancing personal productivity and Parker (1986) who says "Computer tools .. hold great promise for providing students with activities that develop higher level problem solving and thinking skills." (p.21).

The importance of process is reflected in the use of computers to assist students in their written work. The process writing model (Graves, 1983) that stresses the way in which students write, from pre-writing activities to final publication, is widely used in New Zealand schools and fits perfectly with the use of the word processor as a composition tool (CEDU, 1987). Consideration has also been given to the way another tool application - the computer based data management system - can help develop particular metacognitive skills when its use is thought of in process terms (Anderson, 1987).

The cautionary note in the learning with computers thesis is provided by Perkins (1985) who suggests that sometimes opportunities placed at our fingertips by computers may not get taken. Early research into learning with computers supports his call for caution. For example, in a review of LOGO research literature, Krasnor & Mitterer (1984) state:

> In our review of current research we have found no evidence that the LOGO experience with turtle geometry will facilitate the development of general problem-solving skills. Further there is some theoretical reason for doubting that such skills will be developed by the LOGO experience (p.141).

Daiute (1985) reports on research into the use of computers in writing and notes that the students using word processors do not automatically develop higher level editing skills such as block moves. These results indicate that the early claims about the value of learning with computers have yet to be realised.

Despite his cautionary note, Perkins (1985) grants that "first order effects" will occur spontaneously - people will use the tools in ways that they consider convenient, to carry out the same tasks they have always performed. But "second order effects", the qualitatively different ways of thinking and problem solving may not happen because the conditions under which these effects occur are not always met. Perkins explains second order effects by saying:

> In LOGO this means that students using the language will learn the deeper lessons the language affords. In word processing it means that students will recognise and exercise the option of easy large scale editing. In data bases it means that students will formulate interesting questions and harvest answers to them, acquiring along the way a feel for categories and classification (p.12).

Perkins proposes that two different sets of conditions exist which will promote the taking of opportunities to achieve second order effects. One is a "low road" of extensive and varied practice, the other a high road of attention to principles and a mindful approach to problem solving; but to achieve widespread benefit from either approach requires a contriving of those conditions, as may be carried out during schooling. What Perkins' high road approach proposes, a concentration on the principles of problem solving, has been receiving increasing attention within education as a way of helping students to improve their academic performance.

The most recent expression of this particular thrust within New Zealand education is seen in the Report of the Committee to Review the Curriculum for Schools (1987).

This report describes as one of three important aspects of learning, the learning of "...skills which make it possible for students to learn and to apply ... knowledge to their lives..." (1987, p.12). The object of the Committee's interest appears to be the ability of individuals to control and manipulate their own cognitive processes - students should be learning how to learn.

There is a considerable historical background to the area of learning how to learn (Mann, 1979). However, it is only recently, since the beginning of the intensive study of the area of metacognition, that progress has been made towards a clearer understanding of the process of learning to learn. Metacognition, evolving from the information processing approach to the study of cognitive development is said to involve both "...one's knowledge concerning one's own cognitive processes and products...(and)...the active monitoring and consequent regulation and orchestration of these processes..." (Flavell, 1976, p.232).

Research on Metacognitive Skills in Educational Computing

Research into metacognitive abilities has focussed on the monitoring and regulation aspects of cognitive behaviour, following work by Brown and DeLoache (1978). These authors suggested that understanding development of the skills of predicting the consequences of an action or event, checking the results of one's own action, monitoring one's ongoing activity, and reality testing provided the basis for work in this area. Proponents of learning with computers have recognised the importance of metacognition because of the emphasis which study of metacognition places on understanding the processes of learning and problem solving. By concentrating on the process, by having it become a recognised element of the problem solving or learning situation, it is possible also to focus on the ways in which that process can be monitored and controlled i.e. metacognitive strategies and skills can also become specific and available for use by the student.

As stated previously this view relating learning with computers to metacognition has been prominent in educational computing research throughout the 1980's, and has its origins in the work of Seymour Papert. Papert (1980) extolled the virtues of LOGO as a programming language whose use provided experiences in which "...children would be serving their apprenticeships as epistemologists, that is to say learning to think articulately about thinking..." (p.27), and his claims engendered an area of research into development, by students, of such skills as planning, evaluation, and analysis.

The results of work in this area have been equivocal. Some studies have shown that LOGO has positive effects on the development of cognitive and metacognitive skills. Clements and Gullo (1984) found that a group of six year olds improved on tasks measuring divergent thinking, metacognitive skills, reflectiveness and ability to describe directions. Gorman and Bourne (1983) showed that a group given one hour extra tuition in LOGO programming did significantly better on a conditional rule learning task than a group given half an hour extra tuition. However, other studies have found that LOGO programming has little effect on the extent to which such skills are developed. For example, Pea and Hawkins (1984) found that a year of LOGO programming had little influence on children's ability to carry out a sequence of chores, while Pea and Kurland (1984) again argue that LOGO programming is unlikely to promote general problem solving skills. A more recent study by Clements and Nastasi (1988) indicates that peer interaction, which is argued to be a mediating factor in the development of social problem solving and metacognitive skills, was facilitated in both LOGO and CAI environments. Between these groups, the LOGO group showed evidence of enhanced social problem solving skills and a higher frequency of behaviours which indicated metacognitive functioning.

However, the basis of Papert's argument is not just that powerful and general problem solving heuristics can be developed in a LOGO environment, but also that skills learned as students learn to program in LOGO can be transferred across different types of problem, including areas not involving computers. In an investigation of LOGO and transfer of problem solving skills, Mitterer and Rose-Krasnor (1986; see also Krasnor and Mitterer, 1984), conclude that there is little theoretical or empirical support for Papert's view. They base this conclusion on the extensive literature on transfer and problem solving that indicates the need for considerable domain specific knowledge for the development of expertise in a field, and that expertise in one area does not guarantee expertise in another. Thus they say that the learning of LOGO's powerful ideas, and the development of skills and heuristics for problem solving within the LOGO environment will not necessarily lead to effective use of these skills outside that environment. So, a major limitation of educational computing research based on the metacognitive oriented view is that it neglects to consider the importance of domain specific knowledge.

The Importance of Domain Specific Knowledge

LOGO programming is a domain in its own right. As a procedural language LOGO forces attention to the processes of solving problems, but at the same time LOGO programming requires knowledge of the language and its syntax, as well as knowledge of how these elements are combined to write a program. Students may be expert problem solving programmers, but without the requisite knowledge in a different domain, will not show similar expert-like problem solving behaviour in that domain. This illustration distinguishes between various types of knowledge which need defining with more clarity. Metacognitive strategies are taken as being general and global, and domain independent. Domain knowledge is specific and has two forms - declarative and procedural. Declarative knowledge involves knowing about things such as stars, cars, and ferns. Knowing that Achenar is a star is declarative knowledge. Procedural knowledge is knowledge about how to do things such as driving a car or identifying a species of fern. Although these distinctions are artificial in their clarity, the segregation serves a useful function in considering the relationship between these three types of knowledge (Chi, 1987).

This relationship becomes evident when we realise that while metacognitive skills may be able to be transferred from task to task, they are only relevant to a particular task if procedural knowledge which applies to that task is already known. This points to the importance of domain specific knowledge in problem solving and illustrates that metacognitive control strategies can not be seen as powerful problem solving heuristics in themselves. A further critical point is evidenced in the work of Chi (1978; 1985) who argues convincingly that declarative knowledge is also a determining factor in the way strategies are applied. Thus the usefulness of particular strategies in solving tasks is accounted for by the interaction of the knowledge base being drawn on during the task and the metacognitive strategies being applied. This interactive nature of these features of the learning process has been stressed before by Jenkins (1979) and Brown (1982).

The inter-relationship between declarative knowledge and metacognitive strategies is made explicit by Bransford, Stein, Shelton & Owings (1981) in their discussion of the importance of learning to learn. Bransford et al. (1981) say that the learner's task is to understand the relationships between the items of factual information which are available - this is the means by which people gain expertise within a particular area. To do this people "..must ask themselves whether something they already know or have just read can clarify the significance of seemingly arbitrary facts." (Bransford et al., 1981, p.99). People thus operate with respect to their currently acquired and understood knowledge base.

Restated, the task for learners is to activate, using metacognitive strategies, knowledge which can be used to clarify the significance of factual content. The problem of activation of knowledge is a theme in Bereiter and Scardamalia's (1985) work on "inert knowledge" - items of knowledge available to people but not used in problem solving situations. These authors lay stress on the need for a high-level memory search in order to access knowledge of a subject, while acknowledging that the effectiveness of expository writing, their paradigm task, is limited by the writer's knowledge of the subject. Again the interaction of metacognitive strategies and knowledge base is crucial.

Further support for the role of knowledge in problem solving comes from the expert/novice literature. Within this field, differences in problem solving ability have been attributed to both strategy use (e.g. Schoenfeld, 1979) and domain knowledge which a problem solver has (e.g. Chi, Feltovich & Glaser, 1981). With regard to the latter, studies of the organisation of knowledge in memory have shown significant differences between this organisation and expert or novice performance of a task (de Jong & Ferguson-Hessler, 1986; Schoenfeld & Herrmann, 1982).

Finally, the nature of expertise remains to be clarified. To do this a return to the Bransford et al. (1981) work is a first step. These authors regard expertise as being a matter of clarifying the significance of arbitrary facts, of seeking relationships, understanding why these exist and what their purpose is. Glaser (1987) provides further discriminating comment "...In various subject-matter domains, beginners' knowledge is spotty, consisting of isolated definitions and superficial understandings of central terms and concepts. With experience, these items of information become structured, are integrated with past organizations of knowledge, so that they are retrieved from memory rapidly in larger units..." (p.5). As students become more expert their way of structuring knowledge will show more grouping of items, and a greater depth of structure. Relationships between items of data will become more evident and more easily explicated.

Knowledge Organisation

Following the theme of knowledge organisation it becomes necessary to consider in more depth theoretical aspects relating to the way individuals structure or organise their knowledge. That individuals organise material when learning about a topic is not in dispute. The nature of such organisation is debatable.

Chunking of learned material, where chunks serve as functional recall units, is an accepted starting point. Note that chunks are not necessarily units of a particular kind, as Anderson (1980) points out. Concepts are taken as the unanalysable building blocks of cognitive structure, but these can be grouped, or chunked, and a chunk can be encoded and retrieved as a single unit. When chunks are stored in memory in some organised fashion, this organisation serves to facilitate recall. Several types of organisation have been proposed and are supported by research. There is evidence of hierarchical organisation in scripts (knowledge about commonplace events) and categories (e.g., Abbott, Black and Smith, 1985; Barsalou and Sewell, 1985). It is also accepted that there is sequential organisation, especially for scripts and that representation in the form of an associative network may be appropriate (Yekovich & Walker, 1986). A central factor in such variation in organisation is likely to be the assumption about representation upon which empirical findings are based.

The conclusion drawn in the preceding paragraph is similar to the first of three characteristics of the study of knowledge structures which Donald (1987) discusses. Donald's characteristics are:

1) A representation reflects the method of analysis used to produce it;

2) Representations and the methods used to produce them assume differing amounts of structure in the universe; and

3) Representations of cognitive structure can be descriptive or goal oriented, where "..descriptive representations usually consist of a pattern of concepts connected by means of relations, and may describe a proposition or a perspective or any stable state." (Donald, 1987, p.192).

The second of these characteristics illustrates the link between content structure and cognitive structure. There exists a variety of methods which can be used to determine cognitive structure. A strong form of argument suggests that representations of cognitive structure most appropriate for a particular discipline must be those which reflect that discipline's assumptions of content structure. A weaker version of this argument simply says that use of a particular type of representation will indicate the extent to which that representation of cognitive structure can be said to match content structure.

To the extent that students are expected to learn the structure of a discipline i.e., the form and type of relationships between concepts, as well as its factual content, the stronger form of the argument has greater validity for research into cognitive structure. Choice of a method and type of representation of cognitive structure for a domain will be influenced by structure accepted as existing within it. A qualifying point to note is that any form of content structure is based on social acceptance and that for some ill-defined domains there may well be considerable debate about the nature of content structure, and hence about the most relevant form of cognitive representation.

Databases and Knowledge Organisation

The concern with knowledge and knowledge organisation links neatly to the concepts behind databases and database management systems. Databases represent stores of information about a particular domain, while database management systems present the capability of manipulating that information in order to clarify and explicate the relationships between various items of information or classes of items. This capability has been expressed by Hunter (1985) as the database providing the means of:

> Discovering commonalities and differences among groups of events or things.
> Analysing relationships.
> Looking for trends.
> Testing and refining hypotheses.
> Organising and sharing information.
> Keeping lists up to date.
> Arranging information in more useful ways.(p.21).

An ethnographic study of the content and context of use of database management systems (Freeman, Hawkins & Char, 1984) supports Hunter's view of the potential of database use in schools. Freeman et al., (1984) report that teachers mentioned as important aspects of the research process: "...categorising, learning to both generalise and to be more specific, analysing data, reading and organising information critically and effectively, and asking probing questions that relate pieces of information in interesting and unique ways..." (p.13). They also state that the way databases were used in some of the schools they studied, may mean that databases are appropriate tools for promoting these skills. Their qualifications of this conclusion arose mainly from limitations of database software available at the time of the study, limited access to hardware, and insufficient teacher training in implementation of computer activities.

Database use thus provides an integration of "knowledge to be understood" and tools for cognitive strategy use. Of course the information handling capability of the computer may eventually be matched by students using more conventional means. But the speed with which the computer is able to operate allows students to concentrate on asking not just one or two, but a vast range of questions that are important to them. Students also get answers to these questions, questions that they would never have been able to consider asking before because of their own information handling limitations.

Accepting the role of declarative knowledge within the learning to learn and problem solving processes, and the qualitative difference which the use of a computer database could represent, in the broadest unqualified sense there exists a preliminary hypothesis - that students using a database to assist their development of expertise in a specific knowledge domain would become more expert than students using the same information but in conventional form.

By contrast, a purely processing approach would be centred on the confirmation, or otherwise, of the hypotheses that information processing skills or various metacognitive skills would be enhanced. Experimentally based studies relating database use to student learning are extremely few - in fact only two such studies were identified in a search of the ERIC database using the DIALOG Information Retrieval Service during April 1988. One of these, an example of the processing approach, is a study by White (1987). White indicates that the study "...sought to ... discover whether the use of a computer based file management program could contribute to positive gains in students' abilities to locate, gather, organise and evaluate information" (1987, p.356). He goes on to give three specific hypotheses related to these general skills - "Ability to identify data relevant to a given problem" (Hypothesis 1), "ability to identify data that are sufficient to solve a given problem" (Hypothesis 2), "ability to sort information in ways likely to produce a solution to a problem"

(Hypothesis 3) - and then indicates that he expects the hypotheses to be supported because of the element of structure in both materials used and in the file management program itself.

White (1987) reports somewhat contradictory results. An ANOVA performed on the total sample of 28 classes failed to show a significant treatment effect. However with a smaller sample of fourteen classes an ANOVA showed that students using a computer based file management program in conjunction with structured activities achieved significantly greater gains in the researcher designed test of information processing skills than the non-computer, unstructured activity student groups. The reason given for choosing this sub-sample is that data for this group includes a measure indicating verbal ability, an ability that White says is paramount in a set of factors that may enhance skill acquisition. When verbal ability is included as a covariate in an ANCOVA of this subsample's scores on the information processing test, the significance of the treatment effect is slightly greater. Interestingly no reason is given for the contradiction in results between the total group and the smaller sample. Mere possession of data relating to verbal ability does not seem an adequate explanation for the sub-sample to show significant results.

A possible confounding element in White's study is indicated in work by Linde and Bergstrom (1988). These authors carried out a study which investigated the effects of procedural knowledge of table search and declarative knowledge of informational content on the learning of search principles in a relational database. Participants in the study were either trained in searching tables similar to those found in the database, were given information about some of the database content, were given both types of training, or were given neither. Results of the study showed that best performance in the database search task was found for the condition in which only content training was given. Linde and Bergstrom concluded that training on content was the most effective way of facilitating the learning of search principles in a database, which has the implication that a subject's prior level of domain related declarative knowledge influences development and use of skills of information retrieval. White's failure to control for the influence of domain related declarative knowledge is a compelling explanation for the apparent contradictions in his results.

It is precisely the element of structure, which White notes, or organisation of knowledge, on the part of the database user which is behind the skills White identifies in his hypotheses. The abilities White defines are, in practice, dependent on the way users view the data and the relationships which they see existing within them. Differences in these abilities have been shown, in the expert/novice problem solving literature, to be strongly correlated to the problem perception of problem solvers (Chi, Feltovich & Glaser, 1981; Schoenfeld & Herrmann, 1982). The interaction between knowledge and strategies is clearly evident once more.

The preliminary knowledge based hypothesis needs qualification. Perkins (1985) suggests that for students to become more expert there is a requirement that the database use be mindful use. This sound theory-based suggestion is not being investigated here, but rather is introduced as the rationale for development of a particular type of classroom environment. It is clear from Perkins' writing that mindful use is equivalent to stating that use of the database be guided by metacognitive strategies. It becomes necessary to consider how such use can be encouraged. If students are not of themselves using metacognitive strategies to guide their work, such strategies need to be made available to them (Ryba, Anderson & Watson, 1989).

Social Interaction in the Classroom Computer Environment

Work in the area of metacognitive development indicates that metacognitive strategies can be made available through the process of social interaction (Reeve & Brown, 1985). This work is based on Vygotsky's (1978) proposal that metacognition and awareness of self regulating activities has its origins in social interaction. From this perspective two features can be noted. Wertsch (1985) suggests that the origins of self-conscious regulation lie in adult-child interaction, and that during problem solving activities adults interact with children in a variety of ways of varying strategic importance that ultimately shape the independent functioning of the child. Forman and Cazden (1985) focus on the potential contribution to cognitive development and intellectual learning, of social interactions among children themselves. They conclude that while adult-child interactions are paramount in cognitive development, peer interactions may be especially important in school situations since the institutional setting limits the range and type of adult-child interactions. Thus two factors become important in the teaching situation. Firstly students should work in groups, and secondly the role of the teacher is to provide the cognitive "scaffolding", to act as a "..vicarious form of consciousness until such time as the learner is able to master his own action through his own consciousness and control" (Bruner, 1985, p.24). The teacher will guide, support and encourage use of metacognitive strategies as students work with databases.

Interaction between students, teacher and student and student and computer is thus an important component of the classroom learning environment. Despite this, much research work in educational computing has been narrowly focussed on one aspect of learning in asking the question "What is the effect of the computer on..?" (Papert, 1987). Papert is concerned that too often research in educational computing has given "centrality to a technical object - for example computers or LOGO" (p.23) and suggests that experimental research supports such an approach. Pea (1987), in reply, argues convincingly for the use of experimental methods while acknowledging the importance of cultural context in interpretation of experimental results. Salomon and Gardner (1986) point to the need to be aware of both approaches in order to obtain a more complete understanding of the impact of computers on learning.

Ryba (1989), in adapting a model from Erickson (1982), has developed an organisational scheme which demonstrates the relationships between social and cognitive interactions in the classroom computer environment. The scheme graphically illustrates the reflexive nature of relationships between individuals, the immediate environment and the wider social context. The task before teachers and researchers is to attempt to establish computer use in a socially interactive and reflective classroom environment in order to derive the maximum benefit for students from such use. Failure to establish such an environment may mean that database use is ineffective in terms of helping students develop expertise in particular knowledge domains.

Methodological Issues

The preliminary hypothesis stated earlier requires investigation of the way in which students organise their knowledge. In particular it requires use of techniques which infer cognitive structure and allow determination of chunking and integration of those structures. To provide the empirical basis for this present study, it is necessary now to turn to consideration of methodological issues.

A variety of methods have been used to infer cognitive structures. Work by Shavelson (1972; 1974; Shavelson & Stanton, 1975) provided the first extensive examination of cognitive structure. Measures used were based on concept associations where graphic construction, word association and card-sorting tasks were employed to determine concept relatedness. These tasks were followed by hierarchical clustering, graphic representation and multidimensional scaling (MDS) to provide representations of students' cognitive structure.

Three issues are of interest with regard to Shavelson's work. First, use of the analytical methods of hierarchical clustering and multidimensional scaling could be expected to produce diverging results. Divergence would arise because of different assumptions inherent in these methods. While use of multidimensional scaling is preferable with objects which have graded properties (e.g., where colour forms the basis of analysis), hierarchical clustering is to be preferred with objects assumed to form distinct clusters, as with types of animals (Reitman & Reuter, 1980; Sattath & Tversky, 1977). This distinction highlights discussion within the previous chapter concerning content and cognitive structures of knowledge. Assumptions concerning the nature of cognitive structures, such as type of structure assumed, must be made explicit before decisions concerning methods are taken.

With Shavelson's work however, results were somewhat convergent rather than divergent. This initially surprising result leads into the second point. Since the development of cognitive structure from each technique had, in common, derivation of distance matrices as an intermediate stage, such a result is not surprising. To explain, the basic tasks used by Shavelson provide data that is shaped into a triangular matrix in which each entry indicates the distance between concepts that are marked along horizontal and vertical axes. These distances between pairs of concepts are a measure of the similarity between concepts, hence the alternative term, similarity matrix. These matrices form the basis of further analysis.

Use of similarity matrices is problematic. While such a matrix can be developed from many tasks, its application in a mechanical sense removes it from the theoretical base of the data collection. This point is stressed by Reitman and Reuter (1980) who provide two further qualifications:

> distances derived from direct similarity judgements are limited in reliability; they change with the context in which the particular items are judged... (and) ... analyses of distance matrices usually require that the distances involved are symmetric. Yet, in some cases the psychological

processes involved produce distances that are clearly asymmetric (Reitman & Reuter, 1980, p.556).

Similarity matrices do not need to be used in the generation of cognitive structures. An example is given by a study which used a network representation of cognitive structure and was conducted by Chi and Koeske (1983). Free recall sequence was used as evidence of links between dinosaurs and a recall game was used to generate dinosaur-property links. The study, while imposing a form of representation, allowed the inference of cognitive structure directly from protocols of the subject.

Use of interview protocols has also been suggested as an alternative method for obtaining cognitive structure. Recorded interviews can give information concerning what people know about concepts and relationships presumed to exist between them. While this information could be reduced to distance matrices, White (1979) suggested instead that protocols be scored on a set of nine dimensions which relate to cognitive structure. White and Gunstone (1980) used protocols of interviews with students as a basis for construction of propositional networks and scored the interviews on each of the nine dimensions. They were not satisfied with the assumptions lying behind their representations and also had difficulty interpreting the dimensional scores. Interview protocols remain problematic because of the large amount of information which can be obtained and the lack of precisely defined measures which can be used in interpretation of the information.

The third point to arise from Shavelson's work is the desirability of employing several methods as part of an attempt to provide consistency in the inference of cognitive structures. A more recent example of a multi-method approach to the determination of cognitive structure is given by Cooke, Durso and Schvaneveldt (1986). Having used algorithms to obtain both spatial (MDS) and network representations of cognitive structure from the ratings in distance matrices, these authors show how information in all three sources is relevant to recall organisation. Thus two matters become clear. As well as the possibility of converging evidence arising through use of different methods, it seems differing methods may highlight different aspects of cognitive structure. However, different methods applied to gain these kinds of evidence need to share theoretical assumptions for comparisons to have validity.

Consideration of these points restricts the range of methods suitable for inferring cognitive structures. In particular methods excluded would be those that derived cognitive structures through use of distance matrices, while derivation of cognitive structures from interview protocols is not a preferred method. However, reported research which employs such methodologies often highlights other relevant methodological issues which will be noted next.

Based on sorting of problems in maths (Schoenfeld & Herrmann, 1982) and physics (de Jong & Ferguson-Hessler, 1986), these authors derived distance matrices with Johnson's (1967) method of hierarchical clustering being used to infer cognitive structure. Both papers were concerned with expert-novice differences in problem perception. Schoenfeld and Herrmann (1982) used a repeated measures design and showed that cognitive structures could be seen to change over a month-long problem-solving course. This design contrasted with earlier expert-novice studies and was used to avoid some of the ambiguities of contrasting group designs. More significant is support for the notion that identifiable changes occur in inferred cognitive structures after relatively brief periods of instruction.

De Jong and Ferguson-Hessler (1986) focussed on different types of knowledge appropriate for problem solving. Their paper describes how a similarity of the cognitive structures of novices and experts has not always correlated with the ability of novices to solve problems despite the theoretical expectation that it should do so. The contradiction is attributed to attention being paid only to the organisation of concepts in memory. Cognitive structures described in studies for which correlations were not present were inferred from tasks which employed only concepts, in contrast to other studies where several kinds of knowledge (specific declarative or procedural knowledge or general strategic understanding) were used. Their point is that interpretation of the relationship between inferred cognitive structure and measures of performance depends on the relationship between type of knowledge used in the task from which cognitive structure was inferred, and in the performance measure.

Preferred Techniques for Inferring Cognitive Structures

There are four techniques which meet the methodological restrictions outlined in the previous section. Of these, one (Chi & Koeske, 1983) has already been described. The remaining three are used to infer hierarchical structures and are described next.

Means and Voss Enquiry Technique

The first of these was designed to uncover the knowledge structures of expert and novice groups in relation to the "Star Wars" and "The Empire Strikes Back" movies (Means & Voss, 1985). A 'Why..?' question–asking task and a multiple choice test were used to identify known basic action-subgoal-high–level goal sequences within a pre–determined structure. Two further tasks were used to check knowledge of high–level goals regardless of their connection to subgoals or basic actions.

This technique has obvious application to situations where knowledge concerns actions which are goal directed. Its use where the organisation of concepts is being considered is most likely to provide only descriptive information about properties of items and groups of items. It will not necessarily reveal hierarchical arrangements in the data in the way that asking 'why' questions of an action which is related to a higher level goal can do.

Ordered Tree Technique

Reitman and Reuter (1980) used free recall orders in building an ordered tree which represents inferred cognitive structure. Development of this technique (the ordered tree technique or OTT) originated in their critique of distance matrices (noted earlier) and the argued inability of MDS configurations to represent distinct clusters adequately. Also important was the development of the technique in terms of a theory of recall production, and the generation of a structure which represents all regularities in the recall orders. This technique draws on several assumptions:

1) Items are organised into chunks which are recalled as units, with all of one chunk being recalled before moving on to the next;
2) Chunks are mentally ordered into a hierarchical tree; and,
3) Traversal of the structure is constrained by directionality at the nodes (Reitman & Reuter, 1980).

While chunking and hierarchical ordering have been discussed previously, the concept of directionality has not. Three forms of directionality are derived from recall trials:

1) Unidirectional chunks are accessed in only one order, as in reciting the alphabet;
2) Bidirectional chunks are accessed in a single order or its reverse, as in counting up or down a sequence of numbers; and
3) Nondirectional chunks can be accessed in any order (Reitman & Rueter, 1980).

These forms of directionality provide the means to ensure full representation of all important regularities in the data, and allow the recognition of implicit chunks which are important in the process of calculating similarity of ordered trees. Implicit chunks are those overlapping subchunks implicit in directional chunks (see McKeithen, Reitman, Rueter & Hirtle, 1981, p321, footnote 2; Reitman & Rueter, 1980, p.558, footnote 2 for examples).

The technique builds an ordered tree from a series of free recall trials, some of which can be cued in order to encourage variety in recall. The trials are analysed using an algorithm which first identifies sub-trees of the root of the tree, without regard for cueing. Cueing is assumed to disrupt only the traversal of the cued subtree, so undisrupted traversals in any trial can be used to build the more detailed structure for each subtree. The ordered tree thus built indicates structure as well as the directions in which the structure can be traversed. This ordered tree is taken as the representation of cognitive structure. The reliability of the method is fully discussed in Reitman & Reuter (1980) and the technique's validity has been checked using experimental data in which pauses in recall are used as the basis for making inferences about knowledge organisation and chunking. The method has been found to be successful in revealing the underlying organisation in verbal material.

Previous studies using the Ordered Tree Technique have inferred three characteristics about cognitive structures:

1) Depth of organisation (depth) is given by "the average number of nodes between root and terminal items" (McKeithen et al., 1981, p.319). A more structured tree would have a greater depth.

2) Amount of organisation is given by the natural logarithm of the number of possible recall orders (PRO) that can be obtained by traversal of a given ordered tree. For n items without directionality, the unmodified value is n!. It follows that n items ordered in a bidirectional fashion have an unmodified PRO of 2 and if ordered in a unidirectional manner the unmodified PRO is 1. For a

tree the PRO is the natural log of the product of the unmodified values of each chunk.

3) Similarity of pairs of trees is calculated using a definition given by McKeithen et al.:

we define the similarity between two trees as:

$$\frac{\ln(\text{the number of chunks the two trees have in common} + 1)}{\ln(\text{the total number of chunks contained in both trees} + 1)}$$ (p.321).

This similarity measure is not a metric measure and does not distinguish between uni- and bidirectional chunks. Hirtle (1982) suggests that these restrictions may not prove to be overly burdensome in practice.

Use of logarithmic transformations in PRO and similarity measurements deserves comment. For PRO measures, natural logarithms are used because of the extremely large range of the unmodified values. For example, a nondirectional tree with thirteen leaves and no chunking would have 13! (or about 6.23 * 10^9) recall orders. The PRO for such a tree would be 22.55. With an untransformed similarity ratio, trees with a large number of chunks and thus low PROs were distant from all other trees (Hirtle, 1982). However, "..the logarithmic transformation eliminates the significant correlation found between the total number of chunks and the (similarity) ratio" (McKeithen et al., 1981, p.321).

A fourth characteristic is inherent in, and is used as a base for, the previous two characteristics. This characteristic is the chunked nature of cognitive structures inferred using the OTT. A chunk is formed whenever two or more concepts or chunks branch from a node intermediate between them and the root node of a tree. The number of chunks contained in a tree is thus given by a count of the number of nodes intermediate between the leaves of the tree (concepts) and the root node.

A problem with this technique is that it relies heavily on memory performance. Completeness of trials is a crucial element of the algorithm's efficiency and reliability.There is a corresponding reliance on retrieval processes which may, in the event of memory failure, mask the underlying memory organisation. To overcome this problem a modified version of the OTT has been developed (Naveh-Benjamin, McKeachie, Lin & Tucker, 1986). In this newer version concepts chosen to represent the subject matter are provided for subjects to order. There is thus "...less demand on retrieval of the concepts themselves and more reliance on the relationships between the concepts" (Naveh-Benjamin et al. 1986, p.132).

A major question concerning differences between the original and modified versions asks whether or not presenting the concepts for ordering, in comparison with requesting free recall, interferes with representation of memory organisation. Naveh-Benjamin et al. suggest that this is not the case and that the modified technique is a useful way of extracting information relating to cognitive structures developed in practical learning situations.

Concept Structure Analysis Technique

A second technique fulfilling requirements described earlier is the Concept Structure Analysis Technique (ConSAT) developed by Champagne, Klopfer, Desena and Squires (1980). ConSAT was designed for use in achieving two ends. The first was to enable examination of the similarity between content structure and students' cognitive representations of that content. Secondly, it enabled comparison of representations of cognitive structure before and after a period of instruction.

The task requires a subject to arrange a set of terms, written on cards, in a way that reflects how that person thinks about those words. In its original form, terms for the task were derived "...on the basis of their (the authors) assessment of content structure representations communicated through the scientific writings of experts..." (Champagne et al., 1980, p.98).

Hierarchical structures with some transformational elements were derived as "ideal forms" from analysis of the content structure representations found in experts' writing. Student responses to the task were matched against the ideal and classed according to degree of similarity. Hierarchical structures are not imposed upon responses of individuals as occurs with the OTT algorithm, but responses obtained were, however, easily interpreted as being hierarchical in nature (see Champagne et al., 1980). As much as anything this reflects the fact that the concepts chosen for the task were taken from an assumed hierarchical content structure.

In the ConSAT task, relationships between concepts are described by students. This feature of ConSAT makes it substantially different from most other methods which show only that a relationship between two concepts is known to exist, and do not indicate the nature of that relationship. While there is no extra information about a structure in itself, the relationship description does assist in interpretation of structures.

There are several notable differences between these two methods of obtaining information about cognitive structures. ConSAT differs from the OTT in that it gives no information about directionality, and it provides nodes which can be placed in positions between the root and leaf nodes in a tree. Also, when recall orders for OTT analysis indicate that terms are totally unrelated these terms are built into a bush (no chunking). When only a part of the total number of terms are viewed in this fashion they will be seen as leaves connected directly to the root. In contrast, with ConSAT such terms are typically placed distinctly apart from any structure drawn by the subject. Further, in ConSAT subjects are asked to indicate what relationships they see existing between the terms.

Implications for Research Methodology

The purpose of the preceding discussion has been to describe and illuminate matters of concern in regard to choice of technique by which cognitive structure is to be inferred. Starting with the work of Shavelson (1972) and critiques of this work, several issues were investigated that gave rise to limitations on technique. Any methods used to represent cognitive structures should derive them directly from the data, and should not, for preference, be based solely on interpretation of interview protocols. A further requirement is the correspondence of types of knowledge used in performance measures and in the task from which cognitive structure is to be inferred if interpretable correlations between the two are to be made.

With these limitations in mind four techniques were noted as being preferred techniques. Three of these derived hierarchical structures, with one of these three, the Means and Voss technique, being less appropriate when organisation of concepts is being considered. The fourth technique (Chi & Koeske, 1983) infers cognitive structure in the form of associative network. The need for converging evidence, relying on two similar forms of technique, means that the OTT and ConSAT appear to be techniques of choice.

Teacher Assessment and Cognitive Structures

Finally it is noted that teachers have a variety of ways of making their own assessments of changes in student knowledge and understanding of a topic which have developed throughout a unit of work. This research is not concerned with the validity and reliability of these methods, but rather accepts that the assessments which teachers make are an important determinant of student progress through the education system. The conclusions drawn in the preceding paragraphs about the development of expertise, are important in their own right. However a more significant point could be made if the differences, which were argued for there, were reflected in school based assessment tasks which are designed and used by teachers.

As argued previously, the extent of any similarity in significant statistical changes in variables, or significant correlation between cognitive structure variables and teacher test data will be limited by the similarity between type of knowledge used in the task from which cognitive structure was inferred, and in the teacher test. Further to this, cognitive structures inferred give an indication of the ways concepts are related to each other, as evidenced to a certain extent by chunking and depth. A teacher designed test would need to examine student understanding of relationships between concepts as a necessary condition for significant correlations between cognitive structure data and teacher test scores to occur. Since design of teacher tests is outside researcher control no specific hypothesis can be considered, but as empirical matters capable of explanation, correlations and patterns of similarity can be examined from a theoretical base.

Summary

This review began by considering the place of computers in the learning process. Initial optimism about the contribution computers could make to student learning was tempered by the realisation that students would not necessarily take up opportunities offered by computers. Perkins (1985) suggested that working in an environment that concentrates on metacognitive skills would promote the taking of these opportunities.

Papert's (1980) claim that LOGO programming would help students learn to think about their thinking, and lead to improved problem solving abilities, sparked research efforts investigating LOGO use and the development of metacognitive skills, but the evidence in support of that claim is not conclusive. It was argued that the role of domain specific knowledge, and its interaction with metacognitive strategy use, had been neglected in the process oriented view of educational computing research.

Consideration of domain specific knowledge features notably in expert/novice studies. From this expert/novice literature, the organisation of knowledge is revealed as a major distinguishing factor marking the shift from novice to expert. In particular the organisation of declarative knowledge into chunks which become part of a well organised structure is noted as an essential part of expertise.

Databases are also concerned with organisation of knowledge, and provide strategies to manipulate and access information in datafiles. Students who use databases may more easily analyse and organise that information critically and effectively, thus developing greater expertise in a specific knowledge domain, than would students who used the same information in conventional form. This declarative knowledge view contrasts with a processing approach that would look toward improvements in information processing skills, as did White's (1987) study. However, as was noted, declarative knowledge of a domain may influence development and use of skills of information retrieval. This stresses the importance of a knowledge based view of database use that concentrates on the development of domain expertise as a function of declarative knowledge.

A qualification to this knowledge based view stresses the importance of database use in a socially interactive and reflective classroom environment. The most effective use of databases is likely to occur as students use them in a mindful way (Perkins, 1985), and interactions between students, teacher and student, and student and computer contribute to the metacognitive elements of a learning environment so necessary to this mindful use.

Investigation of the way in which students organise their knowledge requires techniques for recording that structure. Methodological issues concerning techniques for inferring cognitive structures have been considered. Several issues relating to techniques were discussed and a set of limitations were noted that led to the Ordered Tree Technique and Concept Structure Analysis Technique being regarded as techniques of choice for inferring cognitive structure.

Intent of the Present Study

The review has noted the general absence of research into database use in schools. Given the widespread promotion of databases as a tool with applicability to many curriculum areas the lack of study of database use is of concern. The present study is an initial attempt to redress this absence of research.

This study will focus on the way in which database use may contribute to the development of expertise by students, in particular knowledge domains. With this focus, concentration will be on knowledge organisation and the way in which this organisation changes over time. The literature indicates that as expertise develops chunking of knowledge is more likely and previously isolated items of data will become structured.

Operationally, this study will work within the methodological limitations noted previously to obtain inferred cognitive structures from a sample of students that will be divided into two groups for comparison purposes. Both groups will take part in normal classroom activities, but one group will work with databases as part of those activities, while the other will not have access to database use. Operational dependent variables will be the number of chunks and the depth of structure with respect to inferred cognitive structures.

The preliminary hypothesis can now be restated as the following specific research hypothesis:

That students using a database as the basis for gaining expertise in a specific knowledge domain will, at the conclusion of a unit of work, have developed cognitive structures pertaining to that domain which:

1) show significantly greater grouping i.e. concepts will be chunked to a greater degree; and
2) show significantly greater depth of structure;

than the cognitive structures of students who use the same information but in a conventional form.

Data gathered as the basis for the acceptance or rejection of the above hypothesis will itself be subject to confirmation by data gathered from an alternative methodology in an attempt to provide converging evidence.

CHAPTER TWO

METHOD

In this chapter details relating to subjects and experimental method are provided. The teaching and learning context will be described, and a section in which assessment procedures will be detailed is provided. A final section on statistical procedures is included.

Overview

A class of 29 students was randomly divided into two groups which were initially matched on the basis of a Computer Attitudes Scale and the Progressive Achievement Test (PAT) Reading Comprehension task. These groups then learnt to use either a word processing or database computer application. The applications were used by students as part of the usual classroom programme. Initial use of applications during two units of work (themes of Food and The Olympic Games) enabled students to become reasonably proficient users. Applications continued to be used during the following two units (themes of Space and Rocks) and with these units, pre- and post-unit evaluation was carried out using tasks for inferring cognitive structure as well as teacher designed unit tests.

Participants

The study was carried out in an Intermediate School of approximately 500 students. Participants were initially 29 students (mean age = 11.6 years, S.D. = 0.12 years) from a Form One classroom comprising 15 girls and 14 boys. Students were randomly assigned to one of two groups. One group was to use database software and activities during classwork on particular units of work while the other would use word processing software. Two female students from the database group left the class soon after assignment to groups and pre-testing. Their scores are not included in any calculations. None of the students indicated that they had used a computer in conjunction with classwork before. Although several from each group reported using computers at home, none had used database or word processing applications previously.

A further group of students was involved in the study. These students were from a Form One class at the same school as the students principally taking part. The class of 27 students was involved on two separate occasions, acting as a no-treatment control group to determine the extent (if any) of practice effects in the main evaluation instrument.

Permission

Permission to carry out the study was obtained from the Wanganui Education Board's Research Committee, the Principal of the school, the teachers of both classes involved and the parents of the students principally involved in the study. A copy of the letter sent to parents and the permission slip which was returned can be seen in Appendix One.

Matching of groups

When assignment to groups was complete students were tested on PAT Reading Comprehension and a Computer Attitudes test to determine the level of matching between the groups in two important areas. (Information about the administration and scoring of the tests is given in Appendix Two).

PAT reading comprehension scores were used as a way of determining the match between groups in terms of their ability to gather information from print materials. High correlations between PAT reading Comprehension and PAT Study Skills (Series 1, 2, and 3) scores indicate that there is a measure of control on student skills involving knowledge and use of reference materials, interpretation of maps, graphs and diagrams, and reading study skills. Similar high correlations with several widely used tests of achievement and intelligence, show PAT reading comprehension scores also give an indication of the extent of equality between groups in terms of general intellectual ability. Form C, the research form of the PAT test was used.

The need for a computer attitude test arises from Salomon's (1983) work on the differential perceptions of information sources. The suggestion is that the attitude to computers as work tools can affect the effort people make to learn and so, with both groups using computers as part of their classwork, a control on this variable is warranted.

There has been little work on validation of computer attitude scales. Bear, Richards & Lancaster (1987) review research in this area and conclude that "..few psychometrically sound instruments for measuring such attitudes have been developed, particularly ones for elementary and middle school students" (p.208). One such instrument is the Bath County Computer Attitudes Inventory developed by Bear et al. No computer attitude scale has been validated for use in New Zealand educational settings and so this instrument was used in its original form as a means of obtaining a best approximation of computer attitudes.

Teacher-Researcher Collaboration

Early in May 1988 a meeting involving the researcher, the school principal and the class teacher was held to discuss the nature of the research in general terms. At the conclusion of this meeting the principal indicated that future contact should be directly with the class teacher and that the research should proceed on a path to be negotiated between and agreed to by the teacher and researcher.

Between this meeting and mid June when initial testing occurred, there were four further meetings with the teacher. One, in conjunction with the teacher's syndicate meeting, had the purpose of explaining the research to other syndicate members. The remainder were discussions that:

1) set a broad timeline for the study;
2) discussed ways of implementing and evaluating success in achieving a metacognitive environment;
3) made initial decisions about topics suitable for the study; and
4) established the rapport between teacher and researcher which provided the basis for continuous fruitful negotiation about roles and procedures throughout the duration of the study.

Classwork Units and Techniques for Inferring Cognitive Structure

Within her long-term plan the class teacher had tentatively proposed a series of units of work for the period of the study. The list was initially Foods, Transport, Space and Swamps. The main limitation on technique proposed in the previous chapter, provided that methods chosen should infer cognitive structure of the same nature as assumed content structure.

Only the final two units were relevant to decisions about technique. The teacher strongly expressed a wish to work with her class on the Space unit, especially with regard to the Solar System. For this area content structure relevant to the student's work can best be described as hierarchical. This point was resolved through discussion between the class teacher, the researcher and a second teacher who is involved, New Zealand wide, in astronomy education. For the Swamps unit decisions about content structure were not resolved. The unit, which had originally been chosen to fit into class preparation for a week-long outdoor education camp, was dropped and replaced by a unit on Rocks fitting the same purpose. Acceptance of the hierarchical nature of the content of the discipline of Geology and in particular the formation and classification of rocks is clear (Champagne et al., 1980).

Practical considerations suggested that techniques for inferring cognitive structure should be easy to administer, preferably on a class basis, and not overly time consuming, given that teaching would be interrupted on four occasions. These considerations along with the need to employ methods inferring hierarchical structures, and the desirability of employing two different methods in an attempt to provide converging evidence, meant that the OTT and ConSAT were best choice techniques.

Thus evaluation techniques involved were OTT and ConSAT and themes for units of work around which evaluation would occur were Space and Rocks. One final change occurred as a result of a decision made within the class teacher's syndicate. The Transport unit was replaced with a unit on the Olympic Games to tie in with the 1988 Olympics.

Evaluation Instruments and Procedures

Three instruments were used to obtain data for analysis in this study - the Ordered Tree Technique (OTT), the Concept Structuring Analysis Task (ConSAT), and teacher designed tests. Use of these instruments varied. The OTT was used as a pre and post instrument for both units of work carried out by the class; the ConSAT was only used at the conclusion of each unit; teacher designed tests were used at the end of each unit, and in addition the test for the Space unit was used as a pre-test. (For information about the administration and scoring of these instruments, see Appendix Three).

Ordered Tree Technique

The OTT was administered to all students as a group on four separate occasions. At the beginning of each unit of class work it was administered as part of an introduction to the topic of study. When each unit was concluded administration of OTT was carried out as part of a review of the topic. During administration students were seated at desks, placed in rows, in their own classroom.

Students were allowed ten minutes without interruption to complete each of four trials. After seven minutes students were advised that they had three minutes left to complete the trial. No student failed to complete any trial within the time allowed. Ten minutes were allowed between trials, with the total administration procedure thus involving a period of seventy minutes. Student responses were coded for, and analysed with, the Fortran program "Tree" developed by Rueter (1985a), that provides ordered trees from recall trials.

The use of only four trials contrasts markedly with the much larger number used by both Reitman and Rueter (1980) and McKeithen et al. (1981). However Naveh-Benjamin et al. (1986) state that a preliminary study using their version of the OTT showed that four trials gives much more structure than three, whereas five trials adds very little to the inferred cognitive structure. This claim is consistent with information provided by Rueter (1985a) about the number of trials which are required in analysis of this type.

ConSAT

ConSAT administration took place on an individual basis beginning the day after post-unit OTT administration. Students were withdrawn throughout the day, with the task being carried out in a small room adjoining the class. ConSAT administration was audio-taped to provide more detailed information about expressed relationships between terms as a supplement to the necessarily brief statements made on the ConSAT sheets.The recorded protocols could be referred to if confusion arose about any reported relationship. ConSAT administration lasted between 10 and 15 minutes.

Teacher designed tests

Teacher designed tests were used as part of the usual teacher/school unit evaluation procedure. As part of pre-research discussions it had been agreed that results would be made available for research purposes. A further aspect of these discussions involved the teacher agreeing to carry out a pre-unit evaluation with the same test. This occurred with the Space unit but the teacher was unwilling to use the test constructed for the Rocks unit as a pre-test.

This decision was made on the basis of the teacher's understanding of her students' knowledge of rocks and their formation and classification. She felt that although her test would be ideal for the conclusion of the unit, if used at the beginning it would result in students perceiving the material and topic as difficult. She wished to avoid this situation which, she argued, would lead to a lack of motivation and consequent disinterest amongst the students.

Teacher designed tests were administered by the teacher with the students in their normal classroom seating arrangement. There was no specific time limit set for the completion of these tests.

Use of the OTT task with the no-treatment control group took place on the day following its use with the main group of participants on both pre- and post-Rocks unit occasions.

Description of Evaluation Tasks

OTT

Students were presented with a set of concepts (words or phrases) arranged in matrix form and were asked to place them in a vertical list in such a way that concepts put close to each other in the list were close to each other in terms of their meaning. Four such sets with accompanying vertical blanks were provided in booklet form on each of the four occasions of testing. The order of the words in each set was chosen randomly. Two of the trials were cued to break stereotypic responses.

The concepts used for the OTT were chosen jointly by the teacher and the researcher as being representative of the content of the unit and as being consistent with the New Zealand Department of Education Syllabus for the class level and subject concerned. Concepts chosen for the OTT for the Space unit were:
Sun, Voyager missions, Project Apollo, Venus, Mars, Jupiter, Saturn, Uranus, Asteroids, Comets, Earth, Pluto, Space Shuttle, Meteors, Meteorites, Neptune, Eclipse, Mercury.

For the Rocks unit the following were chosen:
Lava, Pumice, Granite, Limestone, Shale, Magma, Slate, Rivers, Wind, Volcanoes, Rain, Sediment, Marble.

ConSAT

Terms used in the ConSAT task were written on pieces of card measuring approximately 10cm by 2.5 cm. These cards were laid out at the top of a sheet of paper (approximately A2 size) and subjects were then instructed to arrange them on the paper so as to reflect the way they think about the terms. When subjects indicated arrangement was completed they were asked to point out the relationships between the cards. As a relationship was indicated a line joining terms was drawn and an expression of the relationship was written along the line. There was no time limit set for the completion of this task.

The rationale used for OTT word choice was used again in deciding on the terms to be used for the ConSAT. Terms chosen for the Space unit were:
Solar System, Sun, Space exploration, Voyager 1, Apollo 12, Planets, Venus, Mars, Jupiter, Saturn, Uranus, Moons, Rocky surfaces, Gas planets, Asteroids, Halley's comet.

ConSAT rock unit terms were:
Rock, Igneous, Sedimentary, Metamorphic, Lava, Pumice, Granite, Marble, Limestone, Shale, Magma, Slate, Sediment.

Teacher designed tests

Space Unit

For this unit a predominantly multichoice test was designed by the teacher. The test only involved questions about content, relying almost entirely on recall of prior knowledge or information studied during the unit. One question involved interpretation of a diagram. (A copy of the test is located in Appendix Three).

Rocks unit

Only one third of this test (in terms of marks allocated) was given over to recall of content. The remainder involved description and understanding of classification procedures as they apply to rocks. (A copy of the test is located in Appendix Three).

Two points relate to these descriptions of the tasks. First, the match between concepts involved in the OTT and ConSAT is great but not perfect. The discrepancy results mainly from the inclusion of intermediate node labels in the ConSAT list. Consequently, there are concepts from OTT which are excluded from ConSAT to keep the task at a manageable level in terms of complexity for students and duration of administration.

The maximum of 17 terms used in a ConSAT task by Champagne et al. (1980) with eighth-grade students (equivalent to fourth form) was initially taken as an extreme upper limit for the number of ConSAT terms. Administration of the ConSAT task for the space unit (16 terms) was a somewhat lengthy procedure and consequently the decision was made to reduce the number of terms in the rocks ConSAT task. Terms relating to erosion and change agencies were removed.

A second point concerns the relationship between performance indicators and OTT concepts. It was noted previously that there should be a correspondence between types of knowledge used in performance measures and in the task from which cognitive structure is to be inferred. This correspondence occurs in the case of the Space tasks but is not so marked in the Rocks unit.

Teaching and learning context

This section brings together many points relevant to the research intervention. Principally considered are teacher's role, units of work, duration of study, physical layout, computer resources and teaching methods employed.

Overview of the intervention

The study occupied a period of approximately four months from mid July to mid November 1988. During this time the class worked on four units of work which were used as the basis for the computer activities. Computer activities during the first two units were based around a need for children to become familiar with database and word processing operations, and students quickly became competent in most aspects of application use. The two remaining units involved children in using skills already taught, as they worked with word processor and database packages as part of their class programmes. With each unit, resource material was made available within the class for student use, and class lessons supplemented individual and small group research. Students were required to complete a variety of activities for each unit with reference to the resource material, class lessons, and their own research.

Rationale for Word Processor Use

The initial decision that both groups should use computer applications was made to allow for the idea that computers and software may directly affect thinking and learning. Papert (1987) describes this as a technocentric view in which the computer is expected to have an effect on academic performance. Such a view is not the basis of this study, but having both groups using computers is a methodological safeguard against alternative explanations of results which could be based on such a view. As further argument for total class use of computers, it can be seen that with both groups using computer facilities students would not readily perceive major differences between the groups.

Word processing was chosen as the alternate computer application for two reasons. First, placing concentration for the second group on writing in a computer environment keeps an emphasis on the development of problem solving skills (Ryba and Anderson, 1989), in line with the approach to database use. Second, the writing process calls for consideration of content as well as discourse components of texts. The interaction of these two components is important in writing since, as McCutchen (1986) points out, "...a good writer can generate adequate elaboration...can use relational links among concepts in the knowledge base to build coherence links in the discourse...can control the linguistic construction that express those various discourse relations..." (p.442).

Finally, the use of word processors within the writing process model of written language is an accepted practice within New Zealand schools. The implementation of this approach maintains the thrust of this study towards realistic integration of computers into classrooms.

Computer resources

The school had a suite of 6 Apple][e clones which were situated in a small withdrawal room some distance from the students' class. The computers were not able to be moved from this room which was just large enough to accommodate groups of 12 - 15 students. A printer was also available, and was kept permanently linked to one of the computers. Physical separation of computers from the classroom brought implications for the researcher's involvement in the classroom learning context which are discussed later.

A "first come - first served" booking system was used to determine afternoon usage, while morning usage was rostered around school syndicates. In effect this meant that class use of the computers during the study was limited to periods in the afternoon.

Software used was "AppleWorks" (Claris, 1988) an integrated package combining word processor, database and spreadsheet. Use of an integrated package ensured that students would be using similar command structures in their operation of applications.

Both groups had access to computing resources for approximately equal time periods. This was achieved simply by alternating groups withdrawing to the computer room and, towards the end of each unit, attempting to redress any imbalance in total time spent by allowing students to spend more time at the computers over the last one or two sessions. Over the course of the study groups spent approximately twelve hours each at the computers.

Although twelve hours seems a relatively short period of time, two factors can be raised in explanation. First, learning to use applications did not occur solely on computers. A moderate amount of practice, discussion and explanation occurred in the classroom. Second, once the database group was familiar with the application and its commands, a great deal of their work of formulating questions, deciding on strategies, coding queries for the application could be carried out off the computer. Despite class time not always being used in this way, the database group's need to access computers was considerably less during the last two units and consequently the word processing group had reduced access also.

Unit resource material

Resources available to the students consisted of those available within the school, such as filmstrips, videos and overhead projector transparencies as well as an assortment of print materials. A further selection of books was made available from the National Library Service and several students brought material from home. Databases constructed for use by the students drew solely from material which was available to all students in the class. There was thus an equivalence in the content available to both groups.

Units of work

The class teacher adopted a "centre of interest" approach to classwork units. Thus, having chosen a topic she would incorporate elements of reading, written and oral language, art, social studies, science and health within the unit. Each unit did however have its primary focus on one of these three latter areas. Four topics were studied by the students during the research period. They were Foods (predominantly Health), The Olympic Games (Social Studies), The Solar System (Science) and Rocks (Science). For each unit students were given a range of activities to complete and were expected to use the resources at their disposal for this purpose. The list of activities was the same for both groups. As an example, the Foods unit list is set out in Appendix Four.

Teacher's role

Effective teacher intervention is an essential element of classroom computer environments. In this study two teachers were involved, since physical separation of computers from the class meant that when computers were being used two teachers were required. The researcher, who is a trained teacher, took the part of the second teacher, and was involved initially in helping students become operationally proficient with the database and word processing applications. Beyond this point the researcher's classroom role was defined in negotiation with the teacher.

Aspects of a teacher's role with particular relevance to this study concern the approach to teaching problem solving skills in a computer learning environment, providing the supportive guidance necessary to develop and sustain the metacognitive aspects of the learning environment, and ensuring the absence of "teacher effects" found in previous research studies of computer education.

Use of computers in a class programme brings with it a need to develop and encourage strategies for learning different from those traditionally associated with classroom practice (Ryba and Anderson, 1989). With a database, students spend less time handling and manipulating information and more time discussing, exploring, analysing and checking problem situations and solutions. There is a greater need to stress strategies associated with problem solving skills. Word processing applications make the writing process more workable and allow students to explore, to check, to analyse and to re-work their written material. Many aspects of writing become aspects of a problem solving process (Flower, 1985).

The approach toward teaching and learning of problem solving skills was a mixture of ideas from two sources. From the SPELT program (Mulcahy, Marfo, Peat & Andrews, 1986) came an approach which stressed first raising student awareness of strategies and their usefulness, next teaching strategy use directly and then encouraging modification and extension of strategies. This sequence was adopted as a framework within which the IDEAL approach to problem solving (Bransford & Stein, 1984) was modified for use with strategies appropriate to each computer application.

IDEAL is an acronym whose letters represent stages of problem solving activity: (1) Identify the problem; (2) Define the problem; (3) Explore solution strategies; (4) Act on the strategies; and, (5) Look back to evaluate strategy use. These steps became the outline which was used for both groups in their centre of interest work both on and off the computer.

A further aspect of the teacher's role was to provide for a socially interactive learning environment which emphasised reflective thinking. Teacher questioning was an important element of this aspect, with questions which directed students to look towards their own thinking playing a prominent role in teacher's discourse with students. Further to this, the teacher encouraged students to work with each other in their exploration, analysis, and solution of problems. While most discussions of this type were small group in nature, emphasis in class discussions was also on facilitating student interaction.

Informal evaluations of success in providing a socially interactive and reflective environment for students were undertaken using a checklist of questions for teachers developed by Ryba and Anderson (1989) (see Appendix Five). Although this checklist was designed for use by teachers with database-using students, most of the questions it contains are sufficiently general to apply as guidelines for discussion of the learning environment in which word processor-using students are working.

For example, teachers reflected on, and questioned each other about, the way they would reinforce appropriate student behaviour, their use of follow-up questions, their encouragement for students to think up their own questions for exploration of data, the opportunities they provided for students to restate problems in their own words, and their encouragement for students to reflect on their own thinking.

The last point about the teacher's role concerns the elimination of teacher effects. A meta-analysis of studies of computer based instruction has shown that when different teachers teach computer and conventional groups there is an average effect size of 0.51 SD, in comparison with a difference of only 0.13 SD when the same teacher takes both groups (Kulik, Kulik & Cohen, 1980). To eliminate teacher effects, groups shared teachers following the initial application learning stage. The researcher took three quarters of the computer sessions; in this proportion each group was represented equally.

Use of applications within the units

An aim of the study was to maintain a realistic classroom environment in terms of teaching practice and student activity. School activities can be, and have been, devised which equate computer and non-computer activities (Ryba, Anderson & Chapman, 1986). Such activities typically entail exorbitant amounts of preparation time and are not viable in terms of usual teaching practice. Within this study, it was accepted that use of computer applications provided certain opportunities which might not otherwise realistically be present.

Each unit started with one or two whole class lessons during which the teacher presented introductory material, used questioning and small group discussion to relate concepts involved in the unit to students' prior knowledge, and discussed work required of the students during the course of the unit. Remaining sessions were primarily used by students working to complete the activities.

There were two distinct types of classwork for the groups involved in the study - work involving use of the computer facility and work based in the classroom. Although this distinction provides a useful way of addressing the conduct of the sessions, a more coherent approach which facilitates comparison between groups, is to discuss each groups activities separately with reference to the computer/non-computer distinction.

Word processing group

Off computer work was of two main types. Early in each unit students were involved in exploring the teacher's expression of the required activities and, where applicable, restating these in their own words as problems requiring solution. These student originated problems were recorded on the blackboard and related to the activity they were derived from. For example, in the Solar System unit an activity which concerned finding information about comets, asteroids and moons, and comparing these Solar System elements with each other, generated questions such as "Do any of them go around the sun like the planets?", "Why do moons and comets shine so much?", and "What are they made of?". Where possible the questions themselves were discussed in terms of solution strategies (e.g., How and where would you find out why moons shine?"), and relationship with other information (e.g., "What else might be made from the same material as asteroids?").

Following this students worked individually, in pairs, or in small groups to find answers to the questions they had posed for themselves. Students used the resource material as it was appropriate to them, with complete access to the teacher's overhead transparencies, filmstrips and all print materials. During this early part of the unit the teacher aimed to facilitate student access to and understanding or the material and concepts through questioning and discussion with students. Although such questioning was specifically related to the activity students were researching, it was based around the students' need to develop strategies for problem solving. So, for instance, students would be asked to clarify the problem they were facing (e.g., "What other aspect of our rock data are you trying to relate to rock colour?"), or to break problems into smaller steps (e.g., "Would it be easier to collect information about planet density, then planet diameter, and then compare them all at once?"), or to explain their solution strategies (e.g., "How did you figure out that metamorphic rocks are the hardest group?").

Later in the unit as students formed their notes into written texts, teachers arranged conferences with students to discuss these texts. Conferencing in a process writing environment is mainly aimed at enhancing the quality of written text in terms of its coherence and structure. It also provides students with opportunities to explore content once more, with the teacher and among themselves. Conferences provided the raw material for changes in student texts which were revised, added to, and cut back using the word processor.

For the word processing group, computer use entailed initial input of their texts and then gave opportunities to carry out the revisions noted during conferences and discussions. This revision was a mechanical process - simply using the features of the word processor to move, delete or insert text - but the grouping of students at each computer facilitated further discussion of changes as they occurred. In addition, the teacher encouraged students to explain their understanding of the revised text through questions such as "Why did you make that change? Why is it better written like that?", and to consider the impact of revisions by asking, for example, "Is the point you're making clearer now?", and "Do the next paragraphs still belong there?".

There was no simple cycle between computer and non-computer use such as research leading to text input, next conferencing followed by revision and then more research. Rather the teacher provided a less structured approach in which students could move easily between the various activities as they worked to complete the requirements of each unit.

Database group

As with the word processing group, there were two main types of off computer work. First, these students were involved in restating the activities presented by the teacher in their own words. This work was done in common with the word processing group and followed the pattern described in the previous section. However, for the database group the more precise nature of a datafile, with records containing specifically categorised information (see Appendix Six for an example of a record from each datafile), meant that further discussion of questions they thought up focussed on generating links between items within the datafiles. For example, one Solar System activity asked students to describe the types of planet in the Solar System and provide an account of their major characteristics. Database students were able to consider planets in terms of surface features, atmosphere, mass and density, as categories for information placed in the datafile, that were most appropriate to this activity. These questions from the database group were built into question sheets by the teacher and used as a basis for work on the computer (see Appendix Seven for examples). The second type of off computer work was the compiling of notes and database printouts into written texts. Database students also conferenced with the teacher and discussed their work with each other, but were constrained to hand written texts and re-writing of these following revisions.

Computer use by the database group was aimed at supplying information to answer the research questions they had posed. Specific strategies for use with databases are restricted to those provided by each specific database. Commands allowing users to arrange data, find particular items of data and select data according to rules are most common and were all available for use by the database group. These data manipulation strategies were supplemented by techniques which gave users the power to change the layout of data on the screen or on printouts, and to view one record or many.

Worksheets designed to help students translate questions into specific database strategies were used, initially as overhead transparencies while students were being introduced to strategy use, then as fill-in sheets for the students once they were familiar with their use. The sheets are useful in helping students plan their work and are also a useful record of actions in case of a need to trace errors (Hannah, 1987). Copies of these worksheets are in Appendix Eight.

Teacher questioning was again an important element during this student research phase. The types of question used by teacher with the word processing group were relevant to, and were used with the database group (see earlier section on word processing group student research work for examples). However, as students were using databases other types of question were also applicable. Students were encouraged to look for and attempt to explain commonalities in sets of data (e.g., "What surface features do moons appear to have in common?"..."Can you explain why (this feature) is most common?"), to discover trends in the records (e.g., "What category changes as temperature of planets changes?"), and, because of the ease of datafile manipulation, to extend their investigation to other categories of information. Database use allowed this kind of focus on content.

Through these explanations and examples of class activities, some differences in teaching environment and practice may be seen. These differences reflect the different opportunities provided by respective computer applications but represent an attempt to realistically integrate computer use into classroom practice.

Follow-up

From the conclusion of the study until the end of the school year the researcher was present in the classroom, working with the students to provide each group with experience of the alternative application. This action was undertaken to ensure equitable treatment of students primarily involved in the study.

Statistical analysis

Testing for differences in group means on PAT Reading Comprehension and BCCAI tasks was carried out using Student's t. This was also used for testing whether significant differences existed between groups on the teacher designed Rocks test, as well as measures of depth and number of chunks obtained from the ConSAT task. T tests were also used to determine whether or not significant differences existed between the "pre-" and "post-unit" OTT measures of the no-treatment control group. Two (group) by two (pre/post) repeated measures analyses of variance were performed to test for significant differences in terms of these two independent variables, and to determine whether there was a significant interaction between them, for OTT depth and number of chunks and for the teacher designed Space test. Fisher's Exact Probability Test was used with dichotomous data relating to changes in chunking.

Statistical significance

A level of significance of 0.05 was taken as being applicable in this study. Thus the probability of incorrectly rejecting the null hypothesis is five percent.

CHAPTER THREE

RESULTS

Results set out in this chapter relate to three aspects of the study. Considered first are statistics relating to matching of groups; next, results for OTT tasks are considered and finally ConSAT results are presented. Raw data on which these results are based are given in Appendix Nine. Due to absenteeism it was not possible to obtain complete data for all subjects. Probabilities reported in the text are corrected to two decimal places.

Matching of groups

Participants in the study were randomly assigned to one of two groups (word processing or database use) and these groups were tested on PAT Reading Comprehension and a Computer Attitudes test. Means and standard deviations on these tasks are given, for each group, in Table 1.

There were no significant differences between the groups on either task. For PAT Reading Comprehension Student's t was $t(25) = 1.26$ ($p=.22$). For the Computer Attitudes test, $t(25) = 0.62$ ($p=.54$).

Ordered Tree Technique (OTT)

An algorithm developed by Reitman and Rueter (1980) was used to obtain ordered trees from the data collected in the OTT task. From these trees, depths and number of possible recall orders (PRO) were calculated and the number of chunks was also counted. Depth calculations were carried out using a Pascal algorithm and PROs were calculated using an algorithm developed in MTS LISP by Hirtle (1986) and modified for use with Salford LISP in this research. This latter algorithm also calculates similarities between any two ordered trees obtained from the same group of recalled items.

No Treatment Control Group

A pertinent starting point is presentation of results for the group of students that was used as a no-treatment control to test for the possibility of practice effects in the OTT task. Table 2 presents the "pre" and "post" means and standard deviations for this group for the depth, PRO and number of chunks derived from the Rocks OTT task. This was the single check for practice effects, there was no check with the Space OTT task.

Tests for differences were undertaken using Student's t statistic (one tailed), but no significant differences were found between any of the "pre" and "post" scores. For depth scores, $t(24) = -0.62$. $p = .27$; for number of chunks, $t(24) = 0.45$, $p = .33$; for PRO, $t(24) = 0.30$, $p = .39$.

Table 1

Means and Standard Deviations on Matching Tasks, by Group

Task	Group	Mean	S.D.
PAT Reading Comprehension	Database[a]	21.17	8.44
	Word Proc.[a]	17.47	6.78
Computer Attitudes	Database[b]	45.00	7.17
	Word Proc.[b]	43.27	7.30

[a] $t(25)=1.26$, $p=.22$
[b] $t(25)=0.62$, $p=.54$

Table 2

Means and Standard Deviations for No-Treatment Control Group

Rocks OTT - Height, Number of Chunks, and PRO.
"Pre-" versus "Post-" comparison.

	Pre		Post	
	Mean	S.D.	Mean	S.D.
Depth	0.90[a]	0.76	0.78[a]	0.67
Number of Chunks	3.20[b]	2.45	3.40[b]	2.20
PRO	12.87[c]	6.88	13.81[c]	7.09

[a] $t(24)=-0.62$, $p=.27$
[b] $t(24)=0.45$, $p=.33$
[c] $t(24)=0.30$, $p=.39$

Treatment Groups

Chunking

The first hypothesis resulting from the earlier review was that post instruction cognitive structures of the database group should show significantly greater grouping i.e. concepts will be chunked to a greater degree than in cognitive structures of the word processing group. A repeated measures analysis of variance was performed to examine this hypothesis for both Space and Rocks units.

Space: Results of this analysis for the Space unit show that there is no significant interaction effect with regard to the degree of pre- and post-chunking of concepts used in the Space OTT task ($F(1,25)=3.49$, $p=.07$). There was a main effect for Pre/Post measures ($F(1,25)=7.02$, $p= .01$) but no main effect for Group($F(1,25)=2.45$, $p=.13$). Table 3 gives means and standard deviations for Groups by Time, and ANOVA summary data are presented in Table 4.

Rocks: Repeated measures analysis of variance indicated that there were significant main effects for both Group ($F(1,23)=4.50$, $p=.04$) and Pre/Post measures ($F(1,23)=6.28$, $p=.02$). There was also a significant interaction effect ($F(1,23)=6.70$, $p=.02$). Means and standard deviations for Groups by Time are given in Table 5 and Table 6 gives ANOVA summary data.

Table 3

Means and Standard Deviations for Number of Chunks - OTT

Space Unit

Pre- versus Post-Unit Comparison

Group	Pre-Unit		Post-Unit	
	Mean	S.D.	Mean	S.D.
Database	3.92	1.62	6.50	2.32
Word Processing	4.01	2.52	4.60	1.40
Combined Groups	4.00	2.13	5.44	2.06

Table 4

ANOVA Summary Data for Number of Chunks - OTT

Space Unit

Pre- versus Post-Unit Comparison (Repeated Measures)

Source	d.f.	M.S.	F-ratio	Probability
G (group)	1	10.21	2.45	.130
T (pre/post)	1	28.17	7.02	.014
GT	1	14.01	3.49	.073
Error (S/G)	25	4.17		
Error (T*S/G)	25	4.01		

Table 5

Means and Standard Deviations for Number of Chunks - OTT

Rocks Unit
Pre- versus Post-Unit Comparison

Group	Pre-Unit Mean	Pre-Unit S.D.	Post-Unit Mean	Post-Unit S.D.
Database	2.64	1.91	4.45	1.75
Word Processing	2.36	1.34	2.43	1.40
Combined Groups	2.48	1.58	3.32	1.84

Table 6

ANOVA Summary Data for Number of Chunks - OTT

Rocks Unit
Pre- versus Post-Unit Comparison (Repeated Measures)

Source	d.f.	M.S.	F-ratio	Probability
G (group)	1	16.37	4.50	.045
T (pre/post)	1	8.82	6.28	.020
GT	1	9.40	6.69	.016
Error (S/G)	23	3.64		
Error (T*S/G)	23	1.40		

Examination of mean scores for both units indicates that there is a tendency for the database group to have a greater number of chunks, post instruction. The statistical significance of this tendency is however inconsistent. To examine further any differences between groups in the nature of chunking, a post-hoc analysis of the change in number of chunks was carried out.

For this post-hoc analysis students were recorded as either increasing, or decreasing/equalling the number of chunks in the post-measure with regard to the pre-measure. A two by two table is thus formed, with the increase - decrease/equal distinction on one axis and the database - word processing distinction along the other. The complete tables for Space and Rocks Units are shown in Tables 7 and 8 respectively.

Fisher's Exact Probability test was used to determine whether or not there were any significant differences between the groups in terms of change in number of chunks. For the Space Unit the change in number of chunks just failed to reach the level of significance (p=.06), while for the Rocks Unit, a significant difference was identified (p=.03).

It can be noted here that Fisher's test gives a conservative indication of the significance of any difference. Tocher's modification of the Fisher test (Seigel, 1956) can be used to alleviate such conservatism. With the Space Unit Table, Tocher's modification would indicate that 84.5% of the cases when such observed frequencies occur should be declared significant at the .05 level.

Table 7

Change in Number of Chunks - OTT

Space Unit, by Group
Pre- to Post-Unit Measures

	Change		
	Increase	Decrease/Equal	Total
Database	10	2	12
Word Processing	7	8	15
Total	17	10	27

Table 8

Change in Number of Chunks - OTT

Rocks Unit, by Group
Pre- to Post-Unit Measures

	Change		
	Increase	Decrease/Equal	Total
Database	9	2	11
Word Processing	5	9	14
Total	14	11	25

Depth

A second hypothesis was that the post instruction cognitive structures of the database group should show significantly greater depth of structure than cognitive structures of the word processing group. Repeated measures analyses of variance were performed to examine this hypothesis for both Space and Rocks units.

Space: Repeated measures ANOVA indicated that there was a significant interaction effect between group and pre- versus post-unit scores ($F(1,25)=4.28$, $p=.05$). There was a significant main effect for time ($F(1,25)=5.10$, $p=.03$) but no main effect for group ($F(1,25)=1.06$, $p=.31$). Table 9 gives means and standard deviations for groups by time. ANOVA summary data are given in Table 10.

Rocks: A pattern similar to that obtained from the Space ANOVA is obtained from a repeated measures ANOVA of the Rocks depth data. There is a main effect for time ($F(1,23)=7.53$, $p=.01$), but not for group ($F(1,23)=1.21$, $p=.28$). The interaction effect is again significant ($F(1,23)=4.33$, $p=.05$). Means and standard deviations are given in Table 11, with ANOVA summary data appearing in Table 12.

These results provide support for the hypothesis of significantly greater post instruction depth of structure in the database group. The main effect for time is also encouraging from an instructional point of view, indicating the overall effectiveness of instruction provided in the class in terms of development of expert-like cognitive structures by students.

Table 9

Means and Standard Deviations for Tree Depth - OTT

Space Unit
Pre- versus Post-Unit Comparison

Group	Pre-Unit		Post-Unit	
	Mean	S.D.	Mean	S.D.
Database	0.93	0.51	1.63	0.59
Word Processing	1.07	0.78	1.13	0.49
Combined Groups	1.01	0.67	1.35	0.59

Table 10

ANOVA Summary Data for Tree Depth - OTT

Space Unit
Pre- versus Post-Unit Comparison (Repeated Measures)

Source	d.f.	M.S.	F-ratio	Probability
G (group)	1	0.45	1.06	.314
T (pre/post)	1	1.63	5.10	.033
GT	1	1.37	4.28	.049
Error (S/G)	25	0.43		
Error (T*S/G)	25	0.32		

Table 11

Means and Standard Deviations for Tree Depth - OTT

Rocks Unit
Pre- versus Post-Unit Comparison

Group	Pre-Unit Mean	Pre-Unit S.D.	Post-Unit Mean	Post-Unit S.D.
Database	0.56	0.45	1.18	0.67
Word Processing	0.61	0.51	0.72	0.58
Combined Groups	0.59	0.47	0.92	0.65

Table 12

ANOVA Summary Data for Tree Depth - OTT

Rocks Unit
Pre- versus Post-Unit Comparison (Repeated Measures)

Source	d.f.	M.S.	F-ratio	Probability
G (group)	1	0.52	1.21	.283
T (pre/post)	1	1.41	7.53	.012
GT	1	0.81	4.33	.049
Error (S/G)	23	0.43		
Error (T*S/G)	23	0.19		

Teacher Tests

There was no specific hypothesis concerning scores that students would attain in this test. The purpose of a pre/post comparison of test scores was to determine whether any similar pattern of main and interaction effects was evident. To this end a repeated measures analysis of variance was carried out on the test scores for the space test that was administered both pre- and post-unit. This type of comparison was not possible with scores from the rocks unit test that were obtainable only from post-unit test administration. However a t-test was used to determine whether there was any significant difference between the groups with regard to post-unit scores in this teacher test. Spearman's rank correlation coefficients were also obtained to indicate the degree of association between the test scores, and depth and number of chunks.

Space: The multichoice teacher designed test was administered both pre- and post-unit. ANOVA data indicates that there was a significant main effect for time ($F(1,25)=20.66$, $p>.001$), that the main effect for computer group was not significant ($F(1,25)=3.37$, $p=.08$), and neither was the interaction effect ($F(1,25)=2.73$, $p=.11$). Means and standard deviations are given in Table 13, and ANOVA summary data are presented in Table 14.

Correlation data, indicating the relationship between scores on teacher designed space test, and depth and chunking variables, is shown in Results Table 15. None of the correlation coefficients reaches the required level of significance.

Table 13

Means and Standard Deviations for Teacher Test

Space Unit
Pre- versus Post-Unit Comparison

	Pre-Unit		Post-Unit	
Group	Mean	S.D.	Mean	S.D.
Database	9.50	2.39	12.42	2.19
Word Processing	8.40	3.15	9.80	3.34
Combined Groups	8.89	2.85	10.96	3.13

Table 14

ANOVA Summary Data for Teacher Test

Space Unit
Pre- versus Post-Unit Comparison (Repeated Measures)

Source	d.f.	M.S.	F-ratio	Probability
G (group)	1	46.05	3.37	.078
T (pre/post)	1	58.07	20.66	<.001
GT	1	7.67	2.73	.111
Error (S/G)	25	13.67		
Error (T*S/G)	25	2.81		

Table 15

Correlations - OTT Depth and Number of Chunks with Test Scores

Space Unit, Pre- and Post-Unit

	Pre-Unit		Post-Unit	
	r	p	r	p
Depth	-.186	.177	.167	.202
Number of Chunks	-.181	.183	.118	.280

Rocks: This test was only given after the unit of work. A one tailed t-test using post-unit test scores indicates that there is no significant difference between the groups ($t(22)= 1.59$, $p=.06$). Means and standard deviations are given in Table 16. Correlation data, relating teacher test scores to chunking and depth variables, is presented in Table 17. There are no significant correlations.

Table 16

Means and Standard Deviations for Teacher Test

Rocks Unit, Post-Unit

Group	Mean	S.D
Database	9.50[a]	2.39
Word Processing	8.40[a]	3.15

[a] $t(22)=1.59$, $p=.06$

Table 17

Correlations - OTT Depth and Number of Chunks with Test Scores

Rocks Unit, Post-Unit

	r	p
Depth	-.003	.495
Number of Chunks	.150	.243

Other Analysis

Previous studies have indicated that there is a high and negative correlation between depth and PRO. Analysis was carried out to confirm that the relationship between measures obtained from the OTT in this study conformed to those of other studies using this measure. This can be seen in all four uses of the OTT as Table 18 shows. There are strong and negative correlations between depth and PRO for the rocks OTT tasks both pre- and post-unit, and moderate negative correlations for the pre- and post-unit space OTT tasks.

Table 18

Correlations - Depth with PRO

Space and Rocks Units, Pre- and Post-Unit

		r	p
Pre-Unit			
	Space	-.395	.021
	Rocks	-.951	<.001
Post-Unit			
	Space	-.367	.030
	Rocks	-.908	<.001

Concept Structuring Analysis Technique (ConSAT)

ConSAT data for analysis consisted of a diagram representing the concepts used in the task and the relationships between them, and an audiotape of the interview during which the ConSAT diagram was constructed. The diagrams were re-drawn as hierarchical trees on the basis of information on the diagram and the student's taped commentary. Re-drawing inter-rater reliability of 93.1% was achieved following collaborative re-drawing sessions, practice re-drawings and finally independent re-drawing of a randomly selected sample of one-half of the ConSAT diagrams, by the investigator and a research assistant.

Inter-rater reliability was obtained as follows:
Given two trees drawn independently from the same ConSAT diagram, the total number of chunks was found by summing the number of chunks present in each diagram. The number of chunks from one tree which were replicated in the other was then determined. Finally, the number of replicated chunks was multiplied by two and expressed as a percentage of the total number of chunks.

Re-drawn trees are used as the basis of an attempt to provide converging evidence in support of the findings of the OTT analysis. As earlier acknowledged, constraints of time limited use of the ConSAT to post-unit administration. Analysis was thus limited to use of t-tests to check for significant differences between groups in terms of depth and number of chunks. It is not possible to provide any index of similarity between the trees but examples of both OTT and ConSAT trees for a sample of participants are provided in Appendix Ten for the purposes of comparison.

Depth

Space and Rocks Units

The one tailed t-tests carried out indicated that there was no significant difference between groups for the space unit (t(24)= 1.65, p=.06) and no significant difference between groups for the rocks unit (t(20)=0.36, p=.36). Means and standard deviations for groups for both units are given in Table 19.

Number of chunks

Space and Rocks Units

T-tests were again used to examine data for significant differences between groups. For the space unit a significant difference was found (t(24)=2.58, p=.01), and for the rocks unit the t value of 0.95, df=20, (p=.18) indicated that there was no significant difference. Table 20 gives means and standard deviations for groups for both units. The database group chunked the concepts to a significantly greater extent in the ConSAT task relating to the space unit.

Test score correlations

Correlation data showing the statistical correlation of ConSAT depth and number of chunks with post-unit test scores is given in Table 21. None of the reported r's reach the .05 level of significance.

Table 19

Means and Standard Deviations for ConSAT Depth

Space and Rocks Units, Post-Unit

Unit	Group	Mean	S.D.
Space	Database	1.76[a]	0.42
	Word processing	1.51[a]	0.36
Rocks	Database	0.81[b]	0.30
	Word Processing	0.77[b]	0.22

[a] t(24)=1.65, p=.112

[b] t(20)=0.36, p=.724

Table 20

Means and Standard Deviations for ConSAT Number of Chunks

Space and Rocks Units, Post-Unit

Unit	Group	Mean	S.D.
Space	Database	5.27[a]	0.79
	Word processing	4.27[a]	1.10
Rocks	Database	3.00[b]	1.16
	Word Processing	2.58[b]	0.90

[a] t(24)=2.58, p=.016

[b] t(20)=0.95, p=.353

Table 21

Correlations - ConSAT Depth and Number of Chunks with Test Scores

Space and Rocks Units, Post-Unit

		r	p
Depth	Space	.226	.133
	Rocks	.326	.069
Number of Chunks	Space	.325	.052
	Rocks	.146	.258

To summarise, significant interaction effects were found between groups for depth of ordered trees for both the space and rocks units. A similar interaction effect was found in the number of chunks variable for the rocks unit, but not the space unit. When the pre-to-post change in chunking was taken as a variable the degree of change was again found to be significant for the rocks unit but not for the space unit. For the ConSAT task only one significant difference was found between the database and word processing groups in terms of depth of structure and number of chunks obtained from knowledge structures inferred from post-unit tasks. Correlations between measures from the ordered tree task and scores on the teacher designed space test were not significant. Lastly, correlations obtained between PRO and depth of ordered trees replicated the findings of previous studies using the Ordered Tree Technique.

CHAPTER FOUR

DISCUSSION

This study investigated two hypotheses relating to change in cognitive structures of students as a function of use or non-use of a computer database management system. It also used different methods to infer cognitive structures in an attempt to provide converging evidence for any change noted. Consideration of the context from which the results arose contributes to both interpretation and understanding of those results. Several sections discuss the results and consider limitations of, and questions related to the study. Points considered relate to differences in instruction, the relevance of using depth and chunking as dependent variables without concern for similarity to accepted scientific descriptions, and the extent to which use of hierarchical trees is acceptable.

Initial Concerns

The OTT was developed for novice-expert studies that did not require measures across time. In this study, concern about the possible occurrence of practice effects lay behind the decision to obtain "pre-" and "post-" OTT measures from a group of students who were not undertaking work on the class topics. With a time difference between OTT tasks of only three weeks, a check for practice effects is extremely relevant. Naveh-Benjamin et al. (1986) did not include such a control group in their study, and work by Schoenfeld and Herrmann (1982) was designed to illustrate differences, that developed across time, between two treatment groups. This present study shows clearly that with students who are not given instruction in the content area on which an OTT task is based, inferred cognitive structures are relatively stable across short periods of time in terms of both depth and number of chunks.

Having established this stability of OTT measures in a no-treatment control group, questions concerning differences arising over time and between treatment groups can have a different focus. Consideration of ConSAT measures in conjunction with OTT results enriches the discussion. Variations which are evident in the results require interpretation.

OTT results demonstrate a marked increase for both variables across both units in terms of time. This is interpreted as showing that there was some significant improvement for the class as a whole in the similarity to expert-like structures. On the basis of these results it may be inferred that what has occurred is a form of restructuring of student cognitive structures.

Restructuring has been thought of in many ways. Most notably, in Piaget's work, restructuring refers to changes in the mode of representation such as the change from sensori-motor to pre-operational modes of representation. Stages of development indicative of these modes are comparatively long term, and these modes constrain children's ability in all domains. Because of the global nature of the constraint, restructuring of this type has been described as global restructuring (Carey, 1985a).

This notion of global restructuring has been attacked on both theoretical and empirical grounds (Carey, 1985a; Chi & Rees, 1983; Donaldson, 1978). A view of restructuring as more domain specific has been proposed by Carey (1985b) and is supported by researchers in the science education field (e.g., Driver & Easley, 1978; Novak, 1977; Osborne & Freyberg, 1985; Osborne & Wittrock, 1983). Novice-expert studies also tend to support the view of restructuring as occurring within specific domains.

It is this specific restructuring, akin to Rumelhart and Norman's (1981) concepts of accretion and tuning of schema, that appears to be occurring with students in the study. While accretion relates to the gradual accumulation of factual information, tuning is said to involve gradual changes in such things as the accuracy of schema to better fit students' interpretation of data and the making of generalisations or constraints relating to schema. Changes occurring through both accretion and tuning can lead to more expert-like structures which are both quantitatively and qualitatively different from their predecessors (Chi & Reese, 1983).

The two elements which are important in this restructuring are the relating of new information to prior knowledge (Vosniadou & Brewer, 1987) and the act of seeking clarification of new facts and relationships (Bransford, Stein, Shelton & Owings, 1981). This latter act must be underpinned by the realisation that relationships exist. Instruction is designed to activate relevant prior knowledge structures and to help students find and clarify relationships. The creation of new higher-order relations between existing concepts occurs in the restructuring which takes place as students take account of their interpretation of new information.

As the results indicate, instruction during the course of each of the units appeared to facilitate the change in cognitive structures for the class as a whole. The presence of interaction effects indicates that restructuring occurred more strongly for the database group than for the word processing group. In terms of the rationale for database use provided earlier, interaction effects are probably present because of an increased likelihood that database using students will have been more effective in finding relationships and discovering trends and commonalities in information they are working with. The work of evaluating these relationships, and relating them to prior knowledge, is also made easier in a database environment.

Informal observations made by the researcher showed that students would often scroll through screens of display looking for examples or counter-examples to relate to discussions about observed trends or relationships. This scrolling strategy was most noticeable with the first two datafiles as the students were still becoming familiar with the search strategies the database offered. For example, as one pair of students were working with the foods file attempting to find high carbohydrate food, the teacher intervened and suggested use of the arrange facility. After brief comments indicating acceptance of the teacher's suggestion, the students (in the teacher's absence) reverted to scrolling data because they were also interested in low fat content. The students were as yet unaware of the way a database arrange facility could be used to enhance their search by arranging each category in turn. Although use of this scrolling strategy diminished considerably with increasing student experience, it was maintained as a viable strategy, especially when a subset of the data records had already been selected for investigation thus limiting the amount of scrolling required. In one instance a pair of students were noted scrolling records to obtain information about the "Revolution Distance" of moons. Previous observation had confirmed that they could use, and had used, the arrange facility. When asked why they weren't using it on this occasion the answer was basically that they enjoyed uncovering incongruities in the data as they scrolled through the records (the student's comment, "It's good to do 'cos sometimes we find things that don't go with the other stuff we're looking at."). Several other students also indicated that this spontaneous discovery of records which appeared to be at odds with most others was the reason they enjoyed looking through the data in this way.

The ease with which information could be accessed, and relationships uncovered by database strategies other than scrolling was a particular feature of the database that students took advantage of on many occasions. During the space unit several groups wished to check whether any planet's moons had an atmosphere. Although scrolling through the entire datafile was a possible strategy for this search, no group attempted it. All used the select facility to show only the records for moons on the screen, with one group adding the rule that an atmosphere be present. This latter group quickly discovered only one moon had an atmosphere, and turned to the task of discovering what was special about that moon. The search, for this group, was a momentary distraction from the task of investigating the relationship between moons and atmospheres. Such a search could be a major undertaking for a Form One student with access only to print materials.

Results of teacher tests for the space unit confirm the effectiveness of instruction, with a highly significant increase in test scores over time. These results give no indication of changes in cognitive structures and should not be seen as related to such cognitive structures in any way. Correlation data that indicate there is no significant association between teacher test scores and OTT or ConSAT variables support this statement, and reasons for this are examined in the later section which considers the use of depth and number of chunks as variables. Results of teacher tests indicate the extent to which students have learnt a required form of the content of units and have been able to retrieve such information during test time. Absence of an interaction effect in the Space unit test indicates that no advantage accrued to the database group in terms of these particular actions.

ConSAT results identify only one significant difference between database and word processing groups - number of chunks generated in cognitive structures inferred during the space unit task. The most likely interpretation for this general lack of significant difference arises from consideration of the nature of the ConSAT task. This task provided concept nodes that were able to be used as cues for grouping. These intermediate nodes may have helped students to recall and clarify relationships which served as a basis for chunking and also depth in a way that was not possible with the OTT task. Both groups may have benefited from the presence of intermediate cues, thus eliminating significant differences between the groups. However consideration of convergence in OTT and ConSAT results is still important.

Because of a difference between OTT analysis (repeated measures ANOVA) and ConSAT analysis (t-test) "significant difference" refers to different things in each case and these are not directly comparable. Using ConSAT to obtain confirmation of OTT results is limited by this, but informal comparison of means and trends within the data identifies some convergence in the results. Two points emerge from this comparison. First, with both OTT and ConSAT the database group had higher means for depth of structure and number of chunks in cognitive structures inferred at the completion of each unit. Second, both tasks show a greater number of chunks in the space unit than the rocks unit, and greater depth in the space unit than the rocks unit. Since none of the means recorded approaches a ceiling level given the number of concepts in each task, there is no reason to expect that either of these points is an artifact of the tasks themselves.

This discussion of results obtained in the study has highlighted the kind of restructuring changes that seem to occur as a function of students receiving computer instruction, and particularly illustrates that restructuring is more likely to occur if students use databases as part of instruction, than if they do not. This focus on products of database use was passive since classroom instruction did not concentrate on structuring knowledge as a primary aim. Interesting educational and research possibilities arise in situations where students are explicitly given the chance to represent and connect details of their school (and out-of-school) experiences as labelled representations of their knowledge. Pea (1987) suggests that such explicit representations will lead to easier transfer of knowledge because of the structure given by the student. Initial work in this area (Dansereau & Holley, 1982; Jonassen, 1987; Novak & Gowen, 1984) has asked learners to consciously interrelate concepts as part of instruction. Indications are that adopting this representational strategy helps learners integrate new information with prior knowledge and facilitates comprehension. These student representations have also been used to provide diagnostic information about student learning of concepts.

Electronic tools that provide a means to construct representations are available. For example, Salomon (1987) describes "The Learning Tool" that lets learners create spatial fields of concepts that can be connected with a variety of lines to indicate different kinds of relationship. Maps built up in this way can be used as a single concept themselves and related to other single concepts or maps. Combining databases, which can be used to make relationships and trends in data clearer, with electronic tools such as "The Learning Tool", which allow easy and flexible representations of knowledge, may facilitate the development of expert-like cognitive structures and expert-like problem solving behaviour as students work within particular knowledge domains.

Context of the study

This section discusses differences which may be seen to exist between database and word processing groups in terms of classroom instruction. It also goes beyond these differences to consider the broader context in which the study took place.

Although this study focusses on products of learning it acknowledges the importance of social and cognitive interactions between students, and teacher and students. Erickson (1982) describes this part of the learning task environment as the enacted learning task environment, in which "...the curriculum of directed instruction, as it is experienced in real life as a learning environment, is always a matter of the content of social relations and the content of subject matter being engaged together in successive moments of real time..." (p.172). This description aptly encompasses the interaction between product and process and illustrates the importance of both aspects. While these classroom interactions form one aspect of the educational environment, other factors relating more broadly to school-based interactions and events also have an impact.

Within the Class

Neither classroom nor school-based interactions and events were controlled or measured in any experimental sense. However, within the classroom, the thrust was to ensure a socially interactive and reflective environment for both groups of students. Two considerations which arise from this ask first, whether such an environment was achieved, and second, whether it was achieved evenly for both groups. A third possibility is to question the assumption that it is in any way meaningful to attempt to "match" the groups in these terms for the purposes of control because of the consequences of providing one group of students - the database group - with an opportunity i.e. access to a set of procedures and ways of representing information, which can not be shared by those in the other group.

Stress on establishing a socially interactive and reflective environment arose from the reasoning that such an environment enhances development and use of metacognitive skills. Perkins (1985) argues that these skills are a necessary part of mindful use of databases. What quickly becomes apparent is that the application of metacognitive skills may be enhanced by the use of computer tools such as databases because of the strategies they make available. For example, during the food unit students were picking low fat foods to include in a diet for a particular group of hospital patients. A computer group commented that the food looked pretty boring. When prompted to revise the data they simply arranged all the food on the fat content from low to high and started reconsidering the items from the bottom up. Tables of food content which were available to the word processing group were arranged on food group. Checking of the kind done by the database group would have entailed a complete search through the items - a time-consuming task and arguably one not worth pursuing.

In the classroom situation, for the group without database access, the question was not one of "Can it be done?" but "Should it be done?"; not one of capability, but one of necessity; not one of competence but rather of time. The very essence of the intervention in the classroom context denies the possibility of equating the metacognitive elements of learning environments for groups involved in the study. Such a conclusion does not however diminish the researcher's and teacher's responsibility to provide for social interaction and to promote reflective thinking in ways which suit the circumstances of each group.

The way in which it was planned to discharge this responsibility is reported in the previous chapter. Ensuring that both groups were treated in an equivalent (but not equal) fashion lay behind the swapping of groups and teachers, and the informal evaluation sessions that the teachers held. A preliminary investigation of the social and reflective nature of the learning environment achieved in this study is reported in Anderson (1989). That study shows that monitoring progress through a task was a continuing behaviour in a typical database session. It argues further that it was interaction between students and the availability, to all, of information on the computer screen that made monitoring an explicit activity. The value of this explicit monitoring was shown in the way students openly evaluated, questioned and reflected on each other's decisions, giving rise to much reconsideration and revision.

Within the study, the intention was to accept the natural flow of the class program in its interaction with both syndicate and school-wide events. This decision meant that disruptions and delays occurred in the timing of lessons, that children were sometimes absent and that change and flexibility were a characteristic of the research in practice. Such occurrences typically involved:

Working around the need for the class to attend practice sessions for the school's torchlight display at a local show;
Excusing three students who were involved in a school debate;
Rescheduling classes when the key to the computer room was unavailable;
Releasing students to participate in sports practice sessions.

Reporting results within the context of these activities strengthens the face validity of this study in educational terms.

A further feature of the study is the brief period of time between pre- and post-unit tasks, with students studying a particular unit for only three or four weeks. In studies involving computer-based interventions which focus on processes of learning - in particular the development of metacognitive strategies - such a period is often considered too short for viable results to be obtained. For tasks concerned with changes in representations of declarative knowledge the timespan is adequate, as was illustrated in the first chapter (Schoenfeld & Herrmann, 1982).

This array of points concerning context indicates that the study was carried out in conditions which were as close as possible to resembling "normal" for this class. There were no special provisions for pupils, who were expected to meet their usual class and school obligations. The class was still obliged to take its turn with school activities and computer access was on equal terms with all other classes. These points further enhance the validity of the study in educational terms.

Depth and chunking as dependent variables

To what extent is a study concerned simply with chunking and depth an adequate study in educational terms? Asking this question implies that results should indicate similarity to some form of accepted cognitive structure; that a desired result is one that shows changes in organisation of concepts, not just in depth and number of chunks. Obviously, from a concern purely with structure, depth and chunking can be supported as variables, because the assumption that hierarchical trees are an acceptable way of organising cognitive structures was made. In educational terms though, these variables may not be as relevant.

Results from the study appear to confirm the educational irrelevance of chunking and depth. There is no significant correlation between either number of chunks or depth and test scores for either unit with either technique. However, students are indeed often required to match their knowledge against a socially accepted form of knowledge since there are syllabus descriptions of specific content areas that students should master. This level of matching though can be rather superficial, requiring only learning by rote rather than an understanding of the nature of concepts and relationships between them. For example, the requirement of the F1 - F4 Science Syllabus that "...a student should be able to ...list the planets of our Solar System and describe their major characteristics..." (p.30), could be met simply through memorisation, without consideration for inter-relationships. Higher test scores may be an outcome of this memorisation of isolated fragments of information, but cognitive structures which can be seen as well integrated will not.

Where teacher tests require more than simple recall of information, asking for indication of understanding of relationships seen to exist in a content area, it would be expected that significant correlations should occur. This will be true where teacher tests are based on accepted scientific explanations, and students have developed cognitive structures based on these explanations. However this view of expertise, where knowledge is well structured and matches in terms of content, is particularly limiting. In fact, Donald (1985) shows that experts have relatively low agreement rates (typically less than 25%) on the importance of concepts basic to a particular knowledge domain. Such evidence tends to indicate that a stress on matching against a particular content representation is unwarranted. In science education this certainly appears to be true. Osborne and Freyberg (1985) discuss children's science learning in terms of the children's prior experience and intuitive ideas about science, and accept that students will construct their own meanings in their attempts to make sense of the world they live in. Further they suggest that all students do not necessarily need to hold accepted scientific explanations. They provide the following suggestions of aims for science education:

1) All children are encouraged "...to continue to develop explanations that are sensible and useful to them..."

2) Without jeopardising 1) they want many children "...to regard at least some scientific explanations as intelligible and plausible and as potentially useful to society, if not to the child personally..."

3) Where possible, without jeopardising the above aims, they would want some children "...to replace their intuitive explanations with, or to evolve their own ideas towards, the accepted explanations of the scientific community..." (Freyberg & Osborne, 1985, p.90).

There is no suggestion that accepted scientific explanations are to be disregarded, rather that such explanations are not the only appropriate outcome in science education. What are also acceptable and appropriate are explanations which are sensible and useful, where the sense and usefulness relate to children's interactions with the world they live in and result from an understanding of the relationships existing in the context of each interaction. Cognitive structures derived on the basis of these understandings will be well integrated and likely to reveal greater depth of structure and number of chunks. In the context of sense and usefulness of explanation, the dependent variables of the study have validity.

An additional point in support of well integrated, expert-like but unscientific explanations is made in a study by Kempton (1986). The study describes the two main models that adults use in describing how a thermostat works. One is the proper "scientific" explanation, the other an "unscientific" explanation in which a thermostat is considered to act in a valve-like manner. Kempton extended this study of models to consider the consequences for energy usage when people acted on their models in situations that were typical of the average (North American) home, with the aim of minimising energy usage. Suprisingly the type of model made little difference, important variation occurring instead between participants who had a well integrated and developed model of a thermostat, in comparison with those who did not. There is utility in having well developed models even when they do not accord with the scientific reality. It seems likely that the dependent variables of depth and number of chunks in cognitive structures do indeed provide some way of recognising these sensible and useful explanations.

Such arguments appear to imply that any well developed explanation is acceptable, reducing education to the task of helping students to clarify their own intuitive notions and nothing more. This is not so. It is to be expected that most sensible but "un-scientific" explanations will contain many elements of "scientific" explanations because we live in a scientific and technologically advanced society, and educators will act to promote conceptual change for students in this "scientific" direction as part of society's broad goals. But in doing so they "...must take care not to insist upon conceptual change at the expense of children's self confidence, their enthusiasm and curiosity about the world, and their feeling for what constitutes a sensible explanation..." (Osborne & Freyberg, 1985, p.90).

<u>Type of Structure Inferred</u>

Hierarchical trees were used as the basis for cognitive structures inferred in this study after consideration of restrictions that should apply to techniques which infer cognitive structures, and the content area being studied. This type of inferred structure has inherent in it the ways of measuring expertise that are employed in this study. The problem with hierarchical trees is that links between items are purely hierarchical. While there was no great difficulty with this feature, especially given the nature of the material employed in the study, there are examples from the ConSAT task which show clearly that students are making links across a structure rather than in a top-down manner. Donald (1983) uses the term hierarchical trees, but indicates linkages across the various levels of a tree in outlining the tree structure of key concepts in a university physics course. The usefulness of methods which would allow for such links becomes evident when the domain knowledge being investigated is not assumed to have a hierarchical structure.

The other way of indicating organisation which met restrictions outlined, but which was not used, was the network representation inferred by Chi and Koeske (1983). This method, in common with semantic networks generally, allows links which are not hierarchical to be made between concepts. However, network representations do not usually allow for variables such as number of chunks and depth of structure. With the Chi and Koeske study though, there are definitely groups of concepts which are more closely related to one another as witnessed by the greater number of inter-item links within these groups than between them. These groups could be described as examples of chunking. There is no obvious counterpart for depth in this type of structure. For work in areas where course content is not as well ordered as in content areas in this study, the Chi and Koeske method or conceptual analysis (Donald, 1984) may provide a more valid indication of cognitive structures than would methods assuming hierarchical representation.

Investigating process

The hypotheses investigated in this study asked questions of the products of learning. This was an acceptable starting point, given the importance of a well structured knowledge base in the development of expertise, since no other studies have investigated database use in such terms. The findings of this research provide a foundation that can be explored and built on, but a foundation that is concerned with only one aspect of database use in education. A second researchable aspect concerns strategies and skills available to and employed by students during class activities. Given the interaction between knowledge base and strategies, differences in cognitive structures identified as occurring between groups lead to an expectation that there were differences in procedural knowledge or metacognitive strategy use. The nature of differences which arose in this regard, how they arose, and the possible implications of such differences for student learning need to be considered. This concerns the process of learning with databases.

A rationale for use of databases in schools has often been related to the development of thinking skills such as analysis, synthesis and evaluation set out in Bloom's Taxonomy of Cognitive Skills (Parker, 1986). Given this rationale, the capabilities of the database are being used to facilitate traditional instruction. In this traditional sense, database use can be understood as a matter of using a computer tool to develop and hone certain problem solving skills, and to achieve a better understanding of material being studied, more effectively and efficiently than is possible without such a tool. The empirical evidence suggests that at least part of this has happened. Database using students have developed more expert-like cognitive structures of the content areas.

An extension of this rationale looks towards development of metacognitive skills as an accompaniment to database use (Anderson, 1987), where important elements of metacognition involve a student's ability to set and understand goals, to have available and decide on strategies, and to monitor their own progress through a task (Palinscar, 1986). In this case stress is on helping students develop cognitive self-management skills which enable them to become teacher independent thinkers.

Discussion of these points concerns the question "How did differences arise...". Because of their executive function, metacognitive strategies must be prime candidates for further investigation, given also the prior argument about differences in application of metacognitive strategies. Research in this regard would be similar to Clements and Nastasi's (1988) investigation of social competence (through observation of student behaviour) and information processing (through recording of student verbalisations) components of problem solving in LOGO or CAI environments. While both environments facilitated cooperative interaction, the existence of shared goals and collaborative decision making within the LOGO environment seemed to enhance specific problem solving skills. A database environment appears to share many of the characteristics of LOGO environments and should be subject to the same sort of investigation to determine whether or not this is the case. However rather than the direct categorization scheme for assessing student behaviour and verbalisations used by Clements and Nastasi, analysis should take explicit account of different perceptions students may have of curriculum material and social interaction (Anderson, 1989). Methods of analysis are available (Barnes & Todd, 1977; Button & Lee, 1987) that allow for the highly indeterminate nature of verbalisations and enable researchers to see how meaning and strategy use evolve. Similarly, interpretative rather than determinate observation techniques should be the basis of information gathering with regard to social behaviour.

One aspect of the process of learning with databases that is of special interest is that students may learn to consider a content area in terms of the classification strategies which databases offer. Drawing heavily on a Vygotskian theoretical base, Salomon (1988) has suggested that mindful use of computer tools may lead to students reconstructing that tool's procedures and functions as part of their own cognitive functioning. Students are then thinking "in terms of" something rather than "about" something, a distinction, originally made by Bransford, Nitsch & Franks (1977), which describes a way of distinguishing expert- and novice-like procedural behaviour. As Salomon (1988) points out "...the difference can be illustrated as that between cultivating skills of analysis as required perhaps by the use of flow charts, and learning to think in terms of flow charts as a cognitive tool of representation..." (p.127). Database use is usually characterised as the former, using the database while developing other skills. In contrast, coming to think about particular knowledge domains in terms of database strategies may provide students with richer ways to envisage relationships between concepts in those domains. This possibility is an exciting prospect for further investigation not only with regard to databases, but also because of the generality of the claim about use of computer tools in education.

CHAPTER FIVE

CONCLUSION

The research reported here has been concerned with use of a computer database management system in a classroom context. In broad terms three questions have been considered. The first is "Why use a database in the classroom?", the second is "How can a database be used effectively in the classroom?", and within the context of the answer to this question, the third is "What is achieved when students use databases in the classroom?". Of these three questions only the third has been the subject of empirical investigation in this present study. Answers to the first two questions have been based on previous research findings and theoretical considerations.

In the execution of this study it was necessary to avoid two possible pitfalls. One is described by Pea and Kurland (1984) as "technoromanticism". A technoromantic view of computer education is one in which there is a naive optimism about the effects of using computers, especially as it concerns the spontaneous development of higher order skills. Pea and Kurland argue that this view is best countered by appropriately designed research to test the validity of such claims. The research reported here was designed, in contrast to the romantic view of computer use, to allow for empirical verification of claims which lie behind the rationale offered for database use in classrooms.

However in making this move towards empirical verification of claims about database use it is essential to avoid the "technocentric" trap described by Papert (1987). The technocentric tendency to give centrality to a technical object such as a computer and the software used with it denies the importance, in education, of teachers, students and the classroom environment. In this present study, the learning environment in which databases were used was felt to be as important as the role databases played in providing access to data, and the way they enhanced students' capability to manipulate data.

The concern about classroom learning environment did not rest entirely with database use. An aim of the study was to promote a socially interactive and reflective environment for learning for the entire class, this being the type of classroom learning environment in which mindful use of computer applications such as word processor and database is most likely to take place. Although both groups thus had the same basis in terms of learning environment, informal observations suggest that the nature of the respective computer applications led to differences in the ease with which metacognitive skills could be applied to particular tasks. When dealing with relatively large amounts of data, database capabilities provided the means for monitoring progress and checking solutions in a way that was not practically possible otherwise.

Stress placed on ecological validity, ensuring that data was obtained from realistic classroom settings, contributed to the formation and maintenance of such differences. The confounding effect that these differences can have in the interpretation of results reflects what would surely be found in schools. Few teachers would justify the time and effort involved in producing materials and devising methods that would give students not using databases the same information access and data manipulation capabilities available to database using students.

Within the context of the classroom environment achieved during the study, it was use of databases which presumably led to to the database group recording greater chunking of concepts in inferred cognitive structures and greater depth of cognitive structures than the word processing group, as indicated by results from the Ordered Tree Technique. This interaction effect occurred against the backdrop of a main effect which indicated significant improvement in these variables for both groups over the time of each unit. Emphasis on the variables of chunking and depth arose from consideration of literature relating to the expert/novice shift, and while these variables are taken as indicators of expert performance, they do not measure expertise in any absolute sense. The changes in cognitive structure can be taken to suggest that students had elaborated old structures and related new information to what was already known. Presumably the assumed role of a database - helping students determine and clarify relationships between items of data - led to the significantly more expert-like cognitive structures of the database group. Use of the Concept Structure Analysis Task provided a measure of convergence which enhances the validity of the Ordered Tree Technique analysis.

Lack of correlation between any of the structure variables and the teacher designed tests raised questions about the validity of the variables in educational terms. Resolution of this point was in terms of the aims of science education set out by Osborne and Freyberg (1985). While success in teacher tests is likely to be an indicator of knowledge of accepted scientific explanations, the development of understandings which are sensible and useful to children is a more appropriate aim. It was argued that while such understandings will to some extent be "unscientific", cognitive structures derived on the basis of such understandings are likely to reveal greater depth of structure and number of chunks. Given the indications that a group using databases, within the classroom environment described, has developed cognitive structures with these characteristics, there is empirical evidence to support arguments for the use of databases in schools.

Limitations of the Study

The design of the study made it necessary to compare two quite small samples in examining for interaction effects between groups. Larger samples would have necessitated the involvement of more than one class in the study. With multiple classes

White (1987) had teachers serve as their own control in a paired classroom to overcome teacher effects. While such a design is possible, (but administratively difficult in primary and intermediate schools where teachers stay with a class for most school lessons throughout the day), for the present study the decision was made to accept the limitations of small sample sizes as the trade-off for ease of control for teacher effects and ease of administration of the study.

Informal observations suggest that siting of the school's computer room some distance from the class, and its small, cramped, and almost spartan nature were factors which detracted from the work which occurred there. Although the conditions under which computer use occurred were typical of the school's use of computers, it is felt that the optimal situation for database use is one in which one or two computers are available in the class enabling students to work in the usual freedom and space of the classroom environment while providing easy access to computers as required.

Two potentially limiting conditions to the conclusion of this study must be considered. The first is the environment in which database use occurs. Data in this study were obtained from students working in a particular kind of environment. Whether or not this socially interactive and reflective environment is a necessary component of effective database use is a question which requires empirical investigation. Lessons learnt from the LOGO experience indicate strongly that the answer would be an affirmative one.

A second qualification relates to the type of use being made of the database. A database can be used simply as a store of information which students use in the same way they would use a book. In this case the benefits of database use are seen as ease of information storage and speed of access to information as students work to locate isolated facts. Some frequently mentioned examples of database use - files of library books, famous people, world records - may often be used in this way. Topics which are rich in relationships between items, and sets of items of data are especially suited for database use that concentrates on identifying and clarifying such relationships. Areas of the physical sciences are obvious examples because of the relevance of classification and cross-classification within those areas. This study focussed on the latter type of use on the assumption that it represents the most effective use of databases for enhancing student learning. Alternative types of use may show different results.

Both limitations just described illustrate the importance of teachers in a classroom computer environment. The determining factor in the type of use being made of a database, and a major factor in building an environment that contributes to learning is the teacher's understanding of how databases can be used most effectively in the classroom.

Suggestions for Future Research

Two broad suggestions were made earlier about possible directions for future research. The first, and the most closely allied to the direction of this study, relates to knowledge structuring and restructuring in a broad sense, but does not consider the detail of mechanisms of restructuring. Cognitive theory and research has repeatedly shown the importance of prior knowledge in learning and acknowledges that restructuring occurs as students elaborate existing knowledge structures, and relate new information to that already known. There is some evidence that making existing knowledge structures explicit may facilitate the restructuring process (e.g., Jonassen, 1987) and make the knowledge more amenable to transfer (Pea, 1987). Searching for corroborative evidence for these initial claims and extending research to consider use of databases, that make relationships and trends in data clearer, in conjunction with explicit knowledge representation techniques, provide an interesting and exciting possibility.

A second direction for research stresses the process of database use. There is a need to investigate student use of metacognitive strategies and social interaction in a database context because of the potential contribution of those areas to differences noted in the results of this present study. That such research should have an interpretative character has already been stressed. The extension of research in this direction involves the possibility that students may start to think about particular knowledge domains in terms of the strategies offered by database use. Research along these lines has been started by Salomon (1988) but initial results are equivocal and questions about the nature of this internalisation, its generalisability, and what can be internalised are still to be settled.

In sum, these two directions illustrate the process-product distinction which was a major starting point for this research. In identifying separate lines of research this distinction has been followed and the strengths of each area and its contribution to student learning can to some extent be ascertained. Most educational computing research to date has followed this distinction also. For example, research surrounding LOGO use has been concerned with the processes of learning, while the earlier research into CAI was product oriented. Despite its similar product orientation, this study acknowledged the importance of the interaction between domain-specific knowledge and metacognitive strategy use and, as the qualifications noted in the previous section show, the need for research which addresses this interaction is becoming clear. With its stress on particular domains, but its background as a flexible learning tool, the database, and surrounding classroom culture, becomes an ideal arena for such investigation.

Finally, it is important to conclude by re-emphasising that the context for human change is always a culture. With regard to computer use, this ecological perspective provides a focus on the learner and the interaction between people, and not on the computer. Metacognitive and cognitive gains may depend on the type, extent, and quality of interaction taking place within the classroom culture which surrounds the use of educational software tools. Linking these social and cognitive concerns is a challenge for those involved in educational computing research who accept the view that computers are empowering tools that enable students to become effective and self-directed learners.

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Appendix One

Permission

This appendix contains a copy of the letter sent to parents requesting permission for their child to take part in the study, and a copy of the permission slip returned.

Ross Intermediate School
Thursday 16 June

Dear Parents

During the rest of this term and for some part of Term Three I wish to work with Mrs. Oatway and the students of her class on a project involving the use of computers in schools. The project involves the students in working with computers using database and word processing software.

The aim of the project is to investigate the effects of computer use on learning in schools. During the project the school work the students do will be the work Mrs. Oatway has planned for them to carry out, but the school's computers will play a particular part in the class programme.

Apart from the use of computers the students will be required to take part in several tasks to provide information which will enable me to divide the class into two equivalent groups . The tasks are intended to allow the groups to be checked on reading comprehension, attitudes towards computers and schoolwork, and skill at retrieving and organising information. The results of all tasks will be kept confidential.

To carry out the project I need your approval for your child to take part. Mr. Gauld, the headteacher, and Mrs. Oatway have already given their approval for the study to proceed. A form requesting permission is attached for you to complete, sign and return to school.

If you wish to have more information about the project please contact Mrs. Oatway at school and she will relay any requests for information to me. Finally, you may wish to note that this project is being carried out as the research requirement for a post-graduate degree in the Education Department at Massey University.

Yours

Bill Anderson.

Form of Consent to Conduct Research

I/We ________________________________ being the
parents/guardians of ____________________________
of____________________________________ (address)
hereby consent to_______________________ (name of child)
being a subject in a research project by Bill Anderson under the general auspices of Massey University, and I/we understand that the general nature of the project is to investigate the effects of computer learning in schools.

I/We have the right to withdraw this consent at any time on written notice being given to the researcher.

Date:

Signed:_________________________________Parents/Guardians

____

Appendix Two

Tasks Used to Match Groups

Information about tasks used to match groups is included in this appendix.

Reading Comprehension Task

The Progressive Achievement Test for Reading Comprehension is published by the New Zealand Council for Educational Research, Wellington, New Zealand. Full details of administration and marking are available in the Teacher Manual which accompanies the test.

Computer Attitudes Task. (Bath County Computer Attitudes Inventory)

A copy of this inventory of twenty-six three-choice Likert items follows.

Administration instructions were as follows:

"This questionnaire has a list of sentences about how you feel about computers in schools. You should read each sentence carefully and say whether you agree with it, disagree with it, or don't know how you feel about it. This is not a test so there are no right or wrong answers. You should work as carefully as you can, making sure you mark every sentence. If you can't read a sentence or have any questions to ask while doing the task just raise your hand. Let's start now by reading the instructions."

Instructions preceding the sentences on the sheet were then read aloud. Students were then asked "Does anyone have any questions?". After questions were answered students were instructed to begin. There was no time limit.

Marking

The task was marked as follows:
"I Agree" scored 2 points for positively worded items and 0 points for negatively worded items;
"?" scored 1 point;
"I Disagree" scored 2 points for negatively worded items and 0 points for positively worded items.

Positively worded items were items 2, 4, 6, 8, 10, 15, 16, 19, 21, 23, 24, 25, 26.

The sentences below examine what you think about computers in school.
Please rate each sentence by circling one of the following answers for each:

A I agree
? I Don't Know
D I Disagree

1. People who like computers are often odd.	A	?	D
2. Working maths problems on a computer is fun, like solving a puzzle.	A	?	D
3. It is easy to get tired of using a computer.	A	?	D
4. Studying computer science in high school would be a good idea .	A	?	D
5. People who use computers in their jobs are the only people who need to study about computers.	A	?	D
6. Learning about computers is interesting.	A	?	D
7. School would be a better place without computers.	A	?	D
8. I enjoy using a computer.	A	?	D
9. Computers are boring.	A	?	D
10.Working on a computer is a good way to spend spare time.	A	?	D
11.Using a computer becomes boring after about half an hour.	A	?	D
12.Learning about computers is something I can do without.	A	?	D
13.Computers are not interesting.	A	?	D
14.Studying about computers is a waste of time.	A	?	D
15.It is fun to figure out how computers work.	A	?	D
16.Computers help people to think.	A	?	D
17.Classroom discussions about the use of computers in society are a waste of time.	A	?	D
18.Studying about the history of computers is boring.	A	?	D
19.Learning about the different uses of computers is interesting.	A	?	D
20.Reading and talking about how computers might be used in the future is boring.	A	?	D

21. Learning about the development of computers is interesting.	A	?	D
22. Learning to program a computer is something I can do without.	A	?	D
23. Learning about computer hardware and software is fun.	A	?	D
24. I enjoy learning about how computers are used in our daily lives.	A	?	D
25. Studying about the uses and misuses of computers will help me be a more responsible citizen.	A	?	D
26. I wish I had more time to use computers in school.	A	?	D

Appendix Three

Evaluation Tasks

Ordered Tree Technique

The format of this task and the concepts used are given in the body of the thesis.

Administration instructions were as follows:
"In this task you are asked to put a set of words in order in such a way that words that mean the same thing or nearly the same thing are put close to each other. The words are given to you on one page of the booklet and on the facing page is a set of lines placed under each other for you to write the words on (show using booklet). If there is no word on the top line you can start with any one you like. When there is a word at the top of the lines you must start with that word, continue with those that go with it and go on from there. Since this is not a test there are no right or wrong answers."

Students were next asked "Does anyone have any questions?". After questions were answered students were told they were allowed ten minutes to complete each trial, and that they would be told when they had three minutes to complete the task.

Responses from the four trials were analysed, using the program "Tree" (Rueter, 1985b), to obtain ordered trees.

Concept Structure Analysis Technique

The format of this task and the concepts used are given in the body of the thesis. This concept structuring task was administered individually. Each student was shown a set of terms, written on pieces of card and placed at the top of a sheet of paper, and the task was explained as follows:
"The aim of this task is for you to show how you think about these words. What you have to do is arrange them on this sheet of paper in a way that shows how you think about them. While you are doing this, or afterwards, you should say why you have arranged the words as they are. As you do this I'll connect the words or groups of words, with a line and then write why you say the words are related or belong together. There are no right or wrong answers, just arrange the words in a way that shows how you think about them."

Students were then asked "Do you have any questions?". When any questions were answered, students were told that there was no time limit, and were asked to begin. The complete session was audio-taped for each student and completed sheets were photographed. Diagrams were later redrawn into tree structures.

Teacher Tests

Copies of teacher-designed tests for the Space and Rocks units follow. These tests were administered by the teacher to the class as a whole. No record of the teacher's instructions to students was kept.

The space test was marked by giving one mark for correctly answering each question and was thus marked out of twenty-five.

The rocks test was marked as follows:
For saying "...why it is the best..." (3 marks)
0 irrelevant response
1 indicates that rocks can be told apart
2
3 Clearly explains how precise sorting is possible

For saying "...why it is the worst..." (3 marks)
0 irrelevant response
1 indicates difficulty in telling rocks apart
2
3 Clearly explains difficulty with key as sorting mechanism

Breakability (5 marks)
0 irrelevant to question
1 awareness of need to distinguish rocks with a particular method
2
3 shows how rocks may be told apart - mechanism outlined
4
5 a precise scale with working "differentiating mechanism" well described

Cloze task (1 mark)

Multichoice (1 mark)

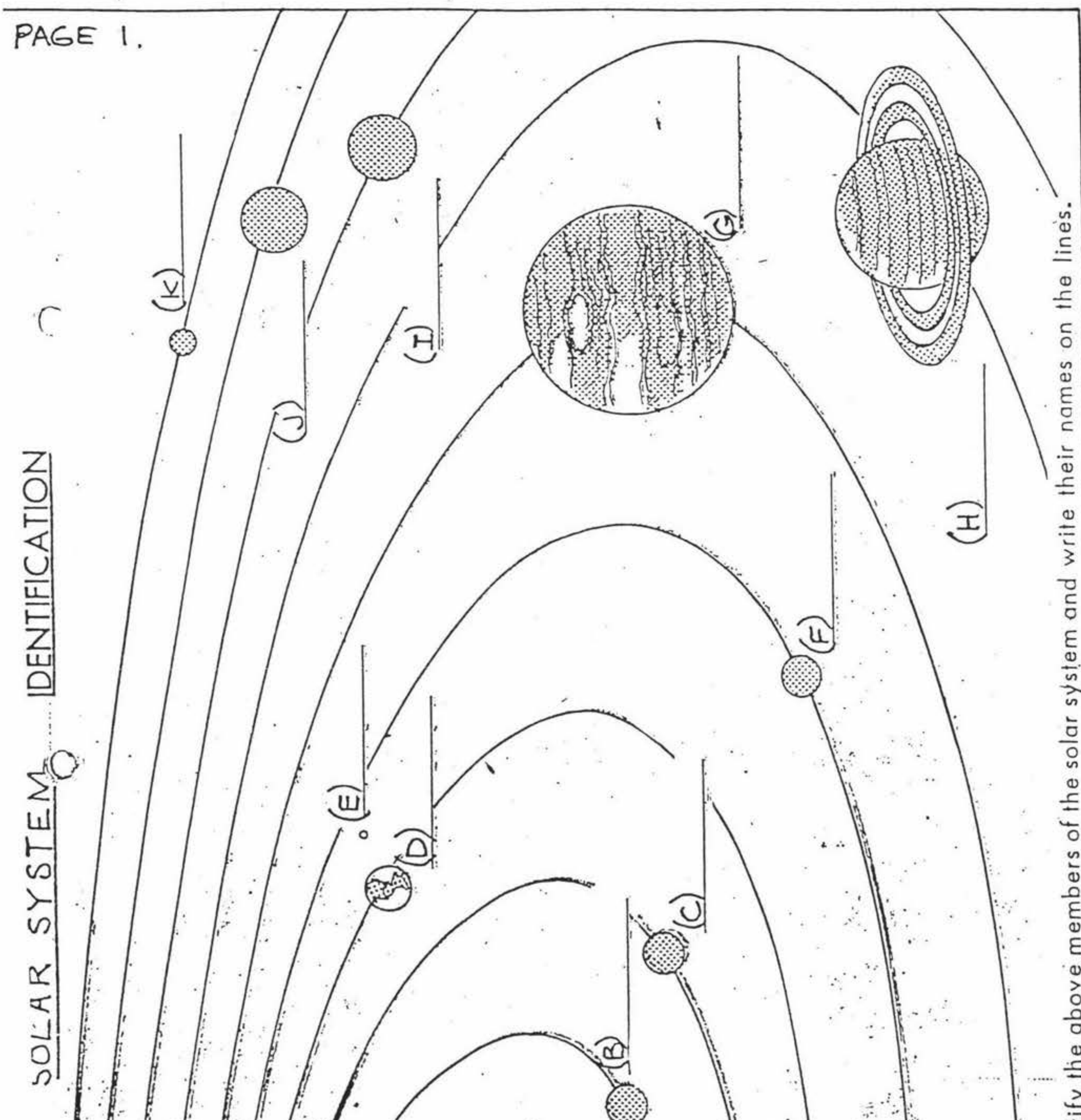
Formation (4 marks)
1 rock type named - formation description unclear and incomplete
2 rock type named -formation elements all present but description unclear
3 clear and complete description of particular rock type formation
extra mark given for reasonably clear accompanying diagram

Teacher Test - Space

Answer ALL Questions

For Question 1 'Solar System Identification' write the name of each object (on page 1) beside the object (Letters A to K).

For Questions 2 to 15 CIRCLE ○ the BEST answer.



1 Use the following list when indicating the positions of the members of the solar system on sheet 1.

Mercury	Venus	Jupiter	Neptune	Pluto	Sun
Earth	Mars	Uranus	Saturn	Moon	

2 Which planets are known to have rocky surfaces?

A Mercury Venus Earth Mars
B Mercury Earth Mars Pluto
C Mercury Earth Mars Neptune
D Earth Mars Uranus Neptune

3 Which planet has an atmosphere of Oxygen and Nitrogen?

A Venus
B Mars
C Earth
D Jupiter

4 Which planets are composed mainly of gas?

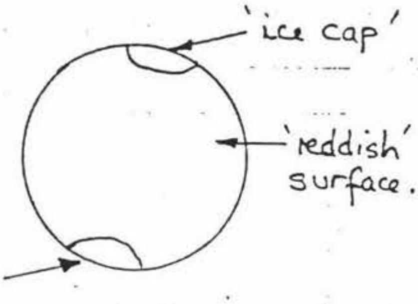
A Mercury, Venus Earth Mars
B Venus Mars Jupiter Saturn
C Mars Jupiter Saturn Uranus
D Jupiter Saturn Uranus Neptune

5 Which planets are known to have moons?

A Mercury Venus Earth Mars Jupiter Saturn Uranus
B Mercury Earth Mars Jupiter Saturn Uranus Neptune
C Venus Earth Mars Jupiter Saturn Uranus Neptune
D Earth Mars Jupiter Saturn Uranus Neptune Pluto

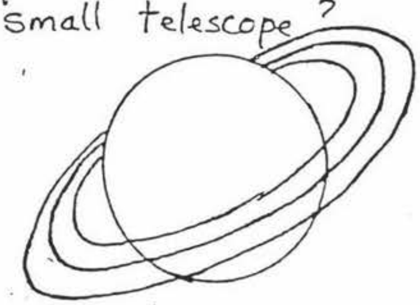
6 Which planet has a 'reddish' coloured surface and polar 'ice caps'?

A	Earth
B	Mars
C	Venus
D	Mercury



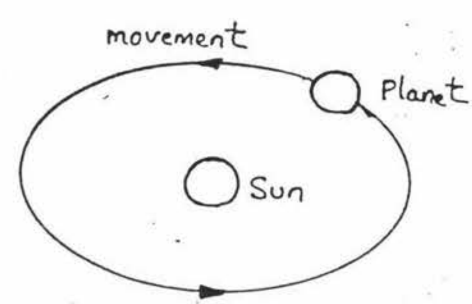
7 Which planet has a system of rings which are clearly visible from earth using a small telescope?

A	Uranus
B	Jupiter
C	Saturn
D	Neptune



8 What name is given to the movement of a planet around the sun?

A	Year
B	Revolution
C	Month
D	Rotation

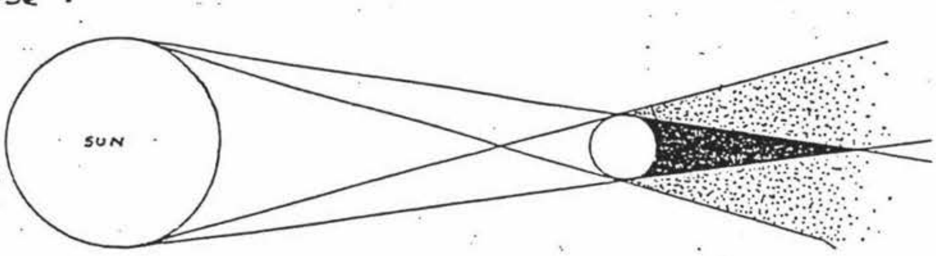


9 What is the name given to the time taken for the earth to revolve once around the sun?

A	an hour
B	a day
C	a month
D	a year

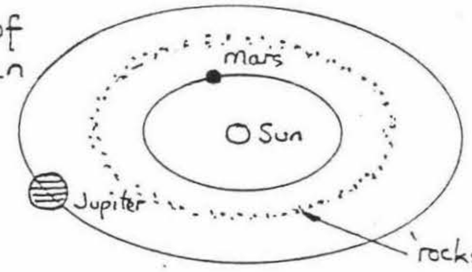
10 What is the name given to the darkest part of the shadow of an eclipse?

A	Umbra
B	Solar
C	Penumbra
D	Lunar



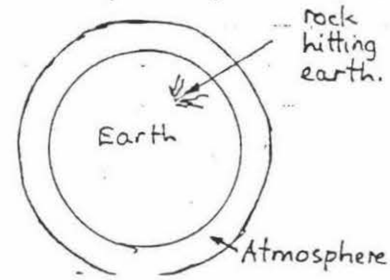
11 What name is given to the belt of rocks that orbit the sun between Mars and Jupiter?

A | Comets
B | Oorts
C | Saturns' rings
D | Asteroids



12 What name is given to particles of rock that enter the earths atmosphere from space and hit the surface of the earth

A | Asteroids
B | Comets
C | Meteorites
D | Meteors



13 Which members of the solar system are sometimes described as 'dirty snowballs'?

A | Meteors
B | Satellites
C | Asteroids
D | Comets

14 Who were the first men to walk on the moon?

A	Collins	and	Aldrin
B	Collins	and	Armstrong
C	Armstrong	and	Aldrin
D	Staffort	and	Young

15 Which planetary spacecraft will be the first to leave the Solar System? If you are uncertain, use the diagram→

A | Pioneer 11
B | Pioneer 10
C | Voyager 1
D | Voyager 2

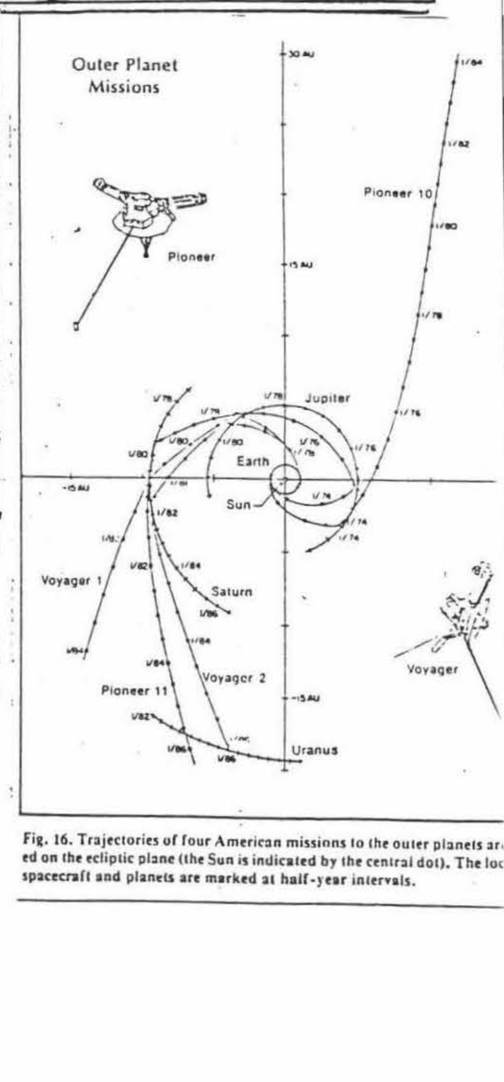


Fig. 16. Trajectories of four American missions to the outer planets ar ed on the ecliptic plane (the Sun is indicated by the central dot). The loc spacecraft and planets are marked at half-year intervals.

EARTH SCIENCE

ROCKS AND MINERALS

Name. ____________________

We used several different ways of sorting rocks. Here are four of them:

Shape
Weight
Colour
Hardness

Which of these do **you** think is the best way of classifying rocks?

____

Now say why **you** think it is the best.
It is the best because ____________________

____

Which one is the worst? ____________________
Say why **you** think it is.
It is the worst because ____________________

____

Say we were to get a new way of sorting rocks. We decided to sort them by how easily they broke into pieces. We need a way to tell the rocks apart from each other just like we did for colour, or texture or touch (or any of the others). How would **you** do it? How would **you** write down its breakability?

____

____

____

____

Complete this.

Volcanoes are found where the earth's crust is ______________________

Which sort of rocks are likely to be found near a volcanic area:

A igneous or fire rocks
B sedimentary or layered rocks
C metamorphic or changed rocks.

Explain how <u>ONE</u> type of rock is made. Choose either igneous, sedimentary or metamorphic. Use the box to draw a diagram which will illustrate your sentences.

____

____

____

____

____

____

____

Appendix Four

Example of Student Task Requirements - Foods Unit

F O O D

Foods activities relevant to database use

1. Hospitals have to cater for a variety of sick people. On many occasions the patients need to be fed a special diet to help them get better. Here are four examples:

   Low fat diets are often needed by people with liver diseases
   High fibre diets can be useful for people with constipation
   Low sugar diets are quite often essential for diabetics
   Low fibre diets are needed after some operations

   You are to pick any three of these four and make up a diet for a day (breakfast, lunch and dinner) which is right for the patient but which still has all the ingredients of a balanced diet. You will need to explain your choice in a paragraph or two.

2. The food pyramid is a way of showing you what it's important to eat lots of, and what you shouldn't eat much of at all. Find out what each of the food groups provide for your diet and why it's important to observe the food pyramid.

3. As a top sportsperson you need to be sure that your body is stoked up with energy before a major event. Remember that only the food you eat for dinner the night before and for breakfast that morning will provide you with "easy to get at" energy. What will you have for dinner and breakfast before the big event?

   A small to moderate amount of sugar is okay but too much sugar is bad. Too much protein is bad. Only a little bit of fat is good. Sugar is a form of carbohydrate.

4. Vegetarians eat no meat or fish. Vegans eat no animal products at all (no eggs, no milk, no cheese...). Can these groups get a diet which provides them with the essential nutrients? Are there any nutrients which they have difficulty getting? What do they have no problems getting in their diet?

5. WORD FIND - find the meanings of:
   peristalsis, carbohydrates, vitamins, minerals, proteins, fats, digestion, saliva.

6. Make a suggestion booklet for parents - "Play lunches and lunches for children" illustrate and remember a balanced Diet.

7. Make up your own advertisement for a food product. Make the reader want to buy it. Include price, nuitrition value and ingredients. Aim to make a million dollars.

8. Research on these famous people (paragraph):

   a) Rěamur
   b) Spallanzaric
   c) Beaumont
   d) Pasteur
   e) Own choice

9. Make up a poem about food that makes your mouth water - illustrate it.

10. Find out about the production of one of these:

    a) ice-cream
    b) flour
    c) spaghetti
    d) sugar
    e) chocolate
    f) own choice

11. Find out about:
    Carnivores, Omnivores, Vegans, Herbivores, Vegetarians

12. IMAGINE you can choose exactly what you have to eat for your BIRTHDAY PARTY. Make it scrumptious! Remember colour is important to taste! **Now** see if you can design your own menu. **Then** write a poem about the best part - eating it.

13. Write a small booklet on seafoods in New Zealand.

14. Find out about:
    a) Health and unhealth foods
    b) Food from other countries
    c) Food songs.

Appendix Five

DATABASE ENVIRONMENT CHECKLIST

This checklist was used in the study to provide a basis for discussion during the informal evaluation sessions that the teachers undertook.

The following checklist provides some of the questions that you might want to ask about the environment in which your students are using databases. Use it to help improve your classroom computer environment.

Database Worksheets

1. Do the worksheets provide a logical sequence of data analysis steps, from the simple to the complex?

2. Do the activities encourage learners to explore the information in the database (e.g., ask their own questions and find answers)?

3. Do the database activities encourage students to plan their solutions systematically (step by step analysis of what they did and how they did it)?

4. Do the activities encourage students to think about their thinking (e.g., define the problem, plan a solution) before going on the computer?

5. Do the worksheets encourage students to try alternative solutions to problems (e.g., arranging the data in different ways to arrive at the same answer)?

6. Do the worksheets encourage students to use systematic methods for locating and fixing mistakes (e.g., find all the occurrences of certain words)?

7. Do the worksheets encourage students to break down complex problems into smaller and simpler problems (e.g., arrange categories, study results, define selection rules)?

8. Do the worksheets promote collaborative learning and shared problem solving?

Teacher Questioning

9. Do you provide individual consultations for the students to help guide them with their problem solving?

10. Do you provide training/instruction while at the same time encouraging students to think for themselves (e.g., trying out different ways of arranging data)?

11. Do you encourage students to break down complicated problems into smaller and simpler ones (e.g., "What is the first thing you need to do to solve this problem?")?

12. Do you reinforce students for creating new ideas and solution strategies (e.g., verbal praise, class recognition)?

13. Do you provide meaningful positive reinforcement to students who engage in the use of problem solving processes (e.g., verbal praise, class recognition)?

14. Do you ask students to explain in their own words how they figured out their solutions to problems?

15. Do you encourage students to think up their own questions based on exploration of the data (e.g., "Can you think of some beginning questions that you might ask about this information?")?

16. Do you encourage students to apply the general problem solving procedures to non-database situations (e.g., "What types of information would you need to analyze the relationship between wind and ground temperature?")?

17. Do you encourage students to be flexible thinkers (e.g., to compare and contrast different approaches to problem solving)?

18. Do you ask questions that clarify the problem (e.g., "Tell me in your own words what you want to find out")?

19. Do you give time to students to answer the question (e.g., count to five before commencing)?

20. Do you ask follow-up questions (e.g., "Why do you think the computer selected only those records?")?

21. Do you encourage students to summarize the problem in their own words as part of their answers (stating the problem for oneself often leads to a solution)?

22. Do you help students to become more fluent thinkers (e.g., "Think of some other databases you could build. What types of information would you need?")?

23. Do you encourage students to synthesize subsolutions into a big solution (providing linking steps to move students from simply exploring the data to examining complex relationships)?

24. Do you ask questions to encourage students to reflect on their own thinking (ask questions which lead to solutions without giving the answer)?

Socially Interactive And Reflective Learning Environment

25. Do you keep your hands off the students' keyboards?

26. Do you encourage students to talk about what they did and how they did it?

27. Do you provide opportunities for learners to work on problems as a group, sharing ways of arriving at their solutions?

28. Do you have class activities that encourage individual students to explain their own thinking to other students?

29. Do you provide adequate time for students to pre-plan their work off the computer (e.g., think about how to arrange categories and to do searches)?

30. Do you provide adequate time for students to work out their solutions to activities on the computer?

Appendix Six

Examples of Datafile Records

File: Form.One.Foods
Report: Form.one.Foods
Selection: FOOD NAME equals APPLE CRUMBLE

FOOD NAME: Apple crumble
FOOD GROUP: Cakes, Puddings
Protein gm/100gm: 3.1
Fat gm/100gm: 7.8
Carbohydrate gm/100g: 49.5
Iron mg/100gm: 1
Vit. B1 ug/100gm: 0.09
Vit. B2 mg/100gm: 0.06
Vit. B6 mg/100gm: 0.7
Vit. B12: No
Vit. C mg/100gm: 3
Sugar: E-High
Fibre: G-Unavailable

File: OLYMPICS.ALL
Report: Olympics
Selection: NAME contains KINGSMAN

EVENT: Backstroke - 200m
SPORT: Swimming
MEDAL: Bronze
NAME: Paul Kingsman
COUNTRY: New Zealand
MALE/FEMALE: Male
DAY: 6
"SCORE": 2:00.48
OLYMPIC RECORD: 1:59.99
WORLD RECORD:

File: Solar System
Report: solar system
Selection: Name equals EARTH

Type: Planet
Name: Earth
Atmosphere: Yes
Gases: nitrogen, oxygen
Surface: Yes
Country:
Destination:
Other info1:
Other info2:
Surface temp: 15
Surface features: Active volcanoes, craters, water, rocky, soil
Length of rotation: 000d 23h 56m
Density: 5.52
Moons: 1
Mass: 1
Revolves around: sun
Revolution distance: 149,000,000
Size - diameter km: 12756
Length of year: 001y
Date:

File: Rocks.Minerals
Report: rocks.minerals
Selection: Name equals OBSIDIAN

Name: Obsidian
Type: Igneous
Smell: None
Colour: Black, grey
Shape: Rectangle
Size: Small
Patterned: No
Touch: Rough
Weight: Light
Texture: Fine
Hardness: 5
Lustre: Bright
Formation: Lava which has cooled very quickly on the earth's surface

Appendix Seven

Examples of Questionsheets Used by Students

The Foods Database

You need to know what each category is, and to find out what is stored in each category. There is a list of category names below. You write alongside the category names the kind of information that is stored in the database.

Food Name lists ____

____

Food Group tells us

____

____

The names of the food groups are:

How many are there? ______________

The categories for **Vitamins B1 B2 B6** tell ___________________

____

The categories for **carbohydrate, protein and fat** tell ____________

____

What are the highest and lowest for each of these categories?

	Highest	Lowest
Vitamin B1		
Vitamin B2		
Vitamin B6		
Carbohydrate		
Fat		
Protein		

____

The information for Vitamin B12 is written as either ________ or ____________. What does this mean? ______________________

____

Sugar and **Fibre** are the two categories left. How many ways does the database use to tell us about the amount of sugar in food?

____

What are those ways? ____

____

____

The amount of fibre is written in lots of different ways too. How many ways are there? __________________

What are those ways? ____

____

____

Keep this! It will be useful during the FOOD unit.

Smelly Rocks

Hardness, colour, weight and now pong.

We had to choose one word from a list and use it to describe the smell of the rocks.

*** What are the four words used the most to describe the smell and how often do they each appear? (Hint: count Earth and Earthy as the same, and Saltwater and Salty as the same).

1____________________ appears ________________times.
2____________________ appears ________________times.
3____________________ appears ________________times.
4____________________ appears ________________times.

Remember how we find patterns by comparing two categories.

We'll compare smell with several of the categories to see what patterns you think there are.

*** Try weight first.

For each of the four main types of smell write down whether the rocks in that smelly group are mainly light, heavy or an even mixture. Remember there are 38 light rocks and 19 heavy rocks all together.

Write it like this.
1 Smell_____________ . The rocks are mainly _____________.

Do the same for the other 3 smells.

*** Try hardness next.

Just look at the two main smell groups, earthy and none. Remember we decided hard was 4 or 5 and soft was 2 or 3.
Is either group mainly soft or mainly hard?
What did you find?

Can you think of any reason for your findings? Try to make a WISE STATEMENT to explain what you found.

*** You may wish to see how some other categories go with smell. I'd suggest you only use the three main smell groups Because they are the only really big ones.

You could try colour or lustre. Write down any patterns that you find and try to say why you think they occur.

Solar system activities

Let's try to find some categories that go together in our file.

1. Can you select all the planets which have rings? Rings are noted in the surface features category.

Get the multi-record form to show Name, Density, Mass, size, and the information on Rotation and Revolution.

What can you say about planets which have rings?

2. Select all the planets which have an atmosphere. Oxide means that a gas contains oxygen. What can you say about the different atmospheres on the planets?

Show Name, Gases, Size,and Revolution distance before you answer.

3. Select only the planets. Use the multi-record layout to show Name, Revolution distance, Size, Temperature and Mass. What category changes as temperature changes?

4. Stay with the planets only.
Show all the surface features, as well as Name, Mass and Density. Is there any connection between surface features and mass or density? What about any other category?

Appendix Eight

Coding Worksheets

ARRANGING WORKSHEET

1.
Question: ____________________

____

____

2. I plan to arrange:

3. Arrange:

1. From A to Z
2. From Z to A
3. From 0 to 9
4. From 9 to 0.

4. I found that: ____________________

____

5. I double checked by: ____________________

____

6. Now I plan to:

____

____

FINDING WORKSHEET

1.
Question:

____

____

2. Terms I plan to find:

____

____

3. Comparison information:

4. I found
that:____

____

5. I double checked
by:____

____

6. Now I plan to:

____

____

RECORD SELECTION WORKSHEET

1.Question:

____

____

____

2.I plan to select those records that:

____

____

____

category connector	logical connector	comparison information	
			and through or ESC
			and through or ESC
			and through or ESC

1. equals	5. is blank	9. ends with
2. is greater than	6. is not blank	10. does not contain
3. is less than	7. contains	11. does not begin with
4. is not equal to	8. begins with	12. does not end with

3. I found that:____

____

4. I double checked by:____

____

5. Now I plan to:____

Appendix Nine

Student Raw Score Data

Student	Group	PAT Rd Comp	Comp Att	ConSAT task: Space Depth	ConSAT task: Space Chunks	ConSAT task: Rocks Depth	ConSAT task: Rocks Chunks	Teacher tests: Space Pre	Teacher tests: Space Post	Teacher tests: Rocks Post
1	DB	15	50	1.25	5	0.67	1	10	13	13
2	WP	10	45	1.82	5	0.62	2	11	11	9
3	WP	15	28	1.50	5	0.62	1	6	8	5
4	DB	24	50	1.64	5	0.92	2	10	15	11
5	WP	11	52	1.46	4	1.08	2	2	6	6
6	DB	19	48	1.25	5	0.67	4	9	13	10
7	WP	23	52	1.83	5			10	15	12
8	WP	9	33	1.31	5	0.81	3	8	10	9
9	WP	16	41	1.38	4			7	6	7
10	DB	34	48	1.91	5	1.00	5	14	15	14
11	WP	30	50	2.15	6			7	12	
12	DB	9	41	2.08	5	0.60	4	5	12	3
13	DB	25	49	1.73	5	1.00	3	8	14	10
14	DB	27	40	2.33	6	1.36	3	11	12	14
15	WP	17	50	1.75	4	0.73	2	11	11	8
16	WP	8	36	1.07	3	1.00	3	5	3	1
17	DB	20	49	1.25	4	0.44	3	10	11	5
18	WP	23	40	2.00	6	0.73	4	13	11	11
19	DB	7	27	2.23	6	0.24	2	11	11	5
20	DB	19	51					6	7	
21	DB	34	49	2.23	5	1.00	3	11	12	11
22	WP	20	39	1.07	3	1.00	4	10	11	4
23	WP	11	42	1.79	5	0.42	2	10	9	3
24	WP	23	43	1.25	3	0.40	3	10	12	10
25	WP	20	47	1.23	3	0.92	2	4	7	7
26	WP	26	51	1.08	3	0.89	3	12	15	10
27	DB	21	38	1.50	7			9	14	

Student	Group	OTT											
		Space						Rocks					
		Pre			Post			Pre			Post		
		Depth	Chunks	PRO	Depth	Chunks	PRO	Depth	Chunks	PRO	Depth	Chunks	PRO
1	DB	0.94	4	12.68	2.00	8	4.16	0.85	5	11.99	0.77	5	12.68
2	WP	0.00	0	36.40	1.00	2	4.79	0.46	0	15.80	0.54	0	15.80
3	WP	1.00	2	22.55	2.00	7	12.75	0.38	2	18.20	0.77	2	11.51
4	DB	0.39	3	30.38	1.28	4	9.91	0.54	1	17.05	1.85	4	7.97
5	WP	2.61	8	13.09	1.50	5	4.56	0.46	3	16.49	1.15	3	10.60
6	DB	0.72	3	24.10	0.89	5	2.08	0.62	3	11.99	1.46	5	11.30
7	WP	2.11	7	17.18	0.77	4	34.20	1.00	2	0.69	1.92	4	6.17
8	WP	0.44	3	1.39	0.61	4	24.26	1.31	4	11.99	0.15	1	20.68
9	WP	1.00	2	19.98	0.83	6	20.27	0.15	1	19.99	0.00	0	22.55
10	DB	1.33	4	25.88	1.06	7	2.08	0.62	4	14.88	1.15	4	12.40
11	WP	1.94	8	3.66	1.66	5	11.70						
12	DB	1.44	5	21.21	2.33	9	4.85	0.69	4	14.88	1.92	6	3.47
13	DB	1.22	6	2.77	1.27	4	2.77	0.46	2	13.49	0.38	2	15.80
14	DB	0.44	3	25.88	2.11	9	4.85	0.23	1	17.50	0.54	3	17.19
15	WP	0.67	2	25.60	1.22	6	6.87	0.00	0	22.55	0.62	3	14.19
16	WP	0.22	2	1.38	0.50	3	20.68	0.15	1	20.68	0.00	0	22.55
17	DB	1.22	7	11.30	1.61	3	3.18	1.69	6	9.76	2.00	7	2.77
18	WP	0.72	5	15.28	0.77	5	18.89	0.54	2	13.49	0.54	3	15.98
19	DB	0.11	1	34.20	1.55	5	21.97	0.00	0	22.55	0.38	2	15.80
20	DB	1.77	5	23.36	1.11	6	21.97						
21	DB	1.16	3	2.48	1.50	8	4.16	0.31	2	18.89	0.62	4	14.19
22	WP	0.50	3	27.68	1.11	3	1.38	0.31	2	18.89	1.54	4	0.69
23	WP	1.67	6	13.38	2.05	6	7.56	1.46	4	8.66	1.23	4	1.39
24	WP	0.55	2	26.40	0.83	3	15.29	0.31	2	17.50	0.15	1	20.68
25	WP	0.67	5	2.08	1.05	5	17.18	0.46	3	15.80	0.54	3	17.18
26	WP	1.88	6	17.18	1.22	5	3.87	1.54	5	4.56	0.92	3	1.39
27	DB	0.39	3	28.59	2.89	10	4.16	0.15	1	19.99	1.92	7	7.56

Appendix Ten

Examples of Inferred Cognitive Structures

This appendix gives 12 examples of cognitive structures inferred from students. There are six examples for each of the last two units (Space and Rocks) and these six are further divided into three each from the database and the word processing groups. Where possible, examples were chosen to show differing amounts of change in the OTT structures. Arrows indicate bi- or uni- directionality in chunks.

Abbreviations are used in the diagrams are as follows:

Space

OTT task

AP	Project Apollo
AS	Asteroids
CO	Comet
EA	Earth
EC	Eclipse
JU	Jupiter
MA	Mars
MC	Mercury
ME	Meteors
MI	Meteorites
NE	Neptune
PL	Pluto
SA	Saturn
SH	Space Shuttle
SU	Sun
VE	Venus
VO	Voyager Missions
UR	Uranus

ConSAT task

AP	Apollo
AS	Asteroids
GP	Gas Planets
HC	Halley's Comet
JU	Jupiter
MA	Mars
MO	Moons
PL	Planets
RS	Rocky Surfaces
SA	Saturn
SE	Space Exploration
SS	Solar System
SU	Sun
UR	Uranus
VE	Venus
VO	Voyager 1

Rocks

OTT task

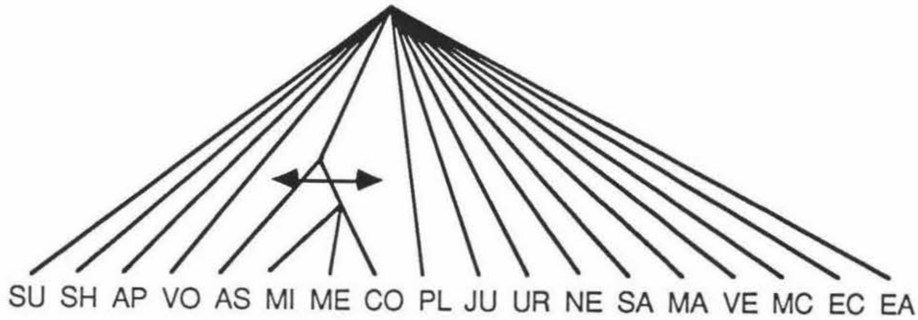
GR	Granite
LA	Lava
LI	Limestone
MA	Magma
MB	Marble
PU	Pumice
RA	Rain
RI	Rivers
SE	Sediment
SH	Shale
SL	Slate
VO	Volcanoes
WI	Wind

ConSAT task

GR	Granite
IG	Igneous
LA	Lava
LI	Limestone
MA	Magma
MB	Marble
ME	Metamorphic
PU	Pumice
RO	Rocks
SE	Sediment
SH	Shale
SL	Slate
SY	Sedimentary

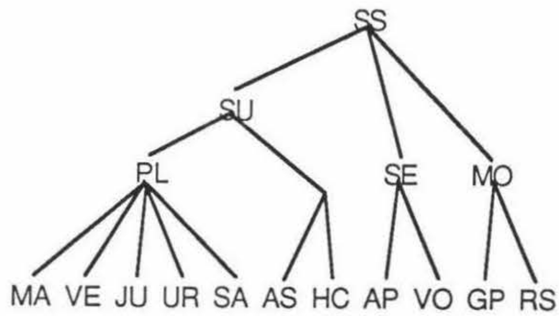
Database student

Pre-space OTT structure

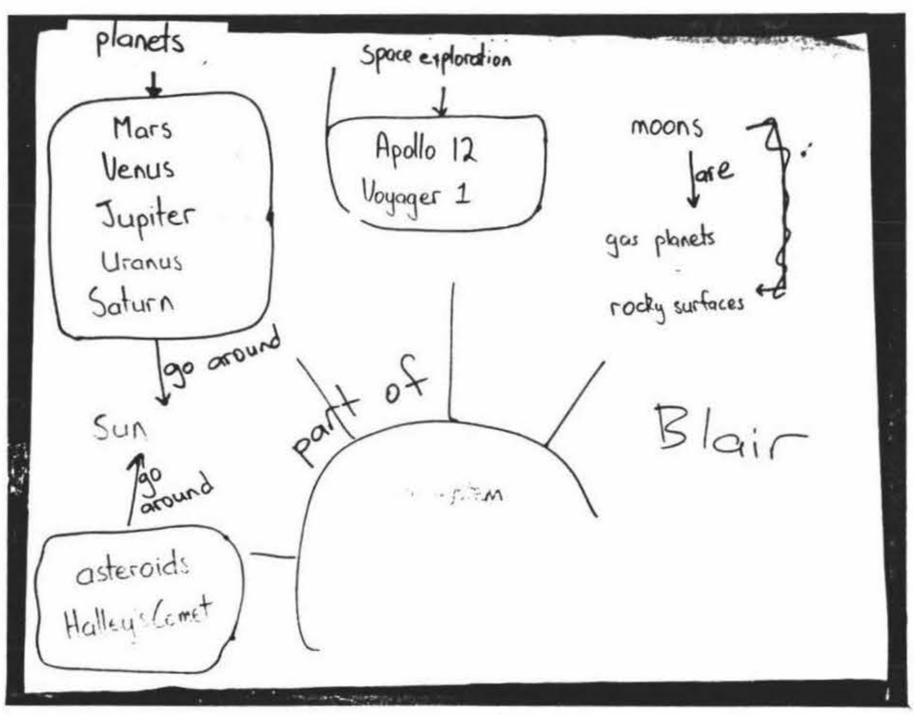


Post-space OTT structure

ConSAT tree structure

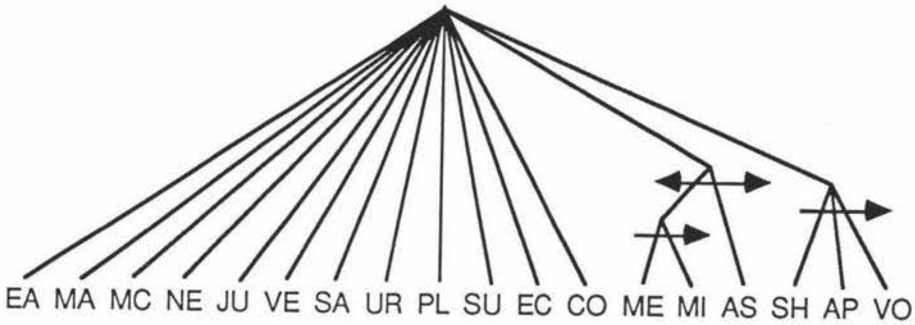


ConSAT diagram

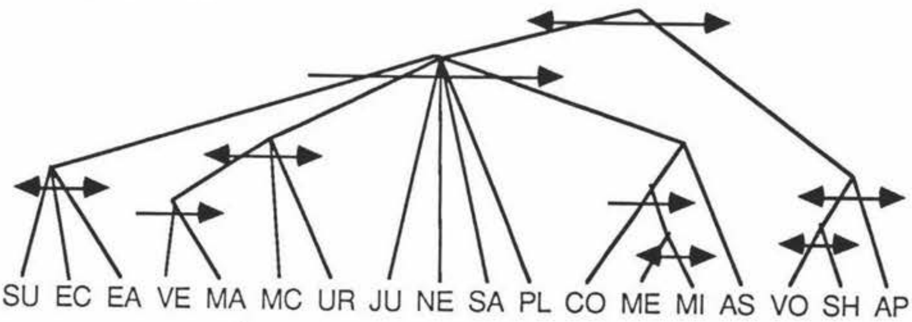


Database student

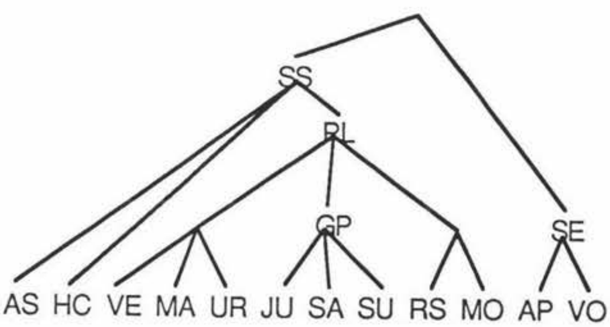
Pre-space OTT structure



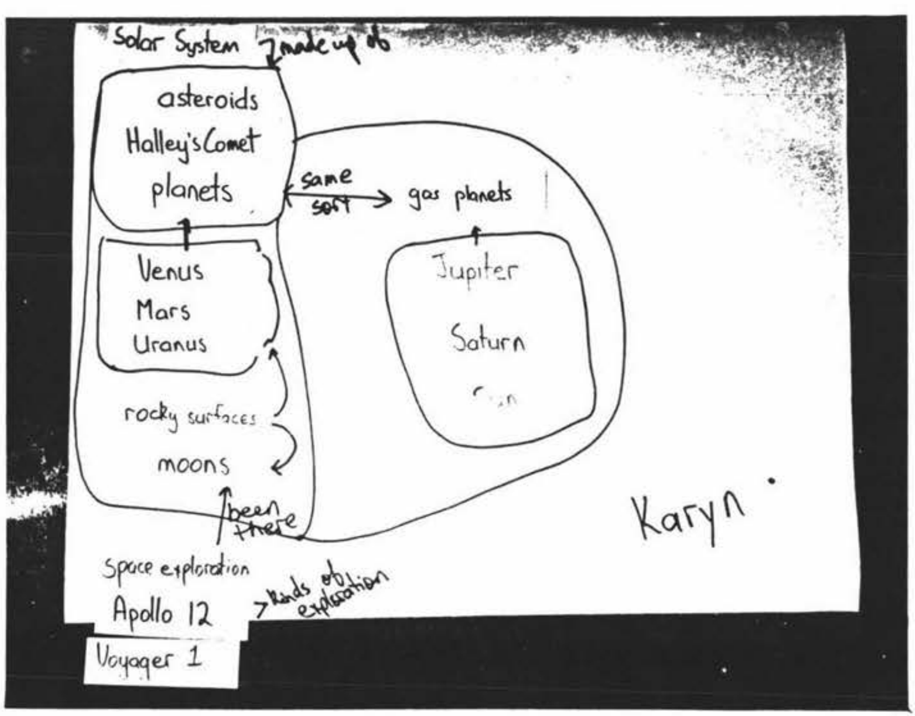
Post -space OTT structure



ConSAT tree structure



ConSAT diagram



Database student

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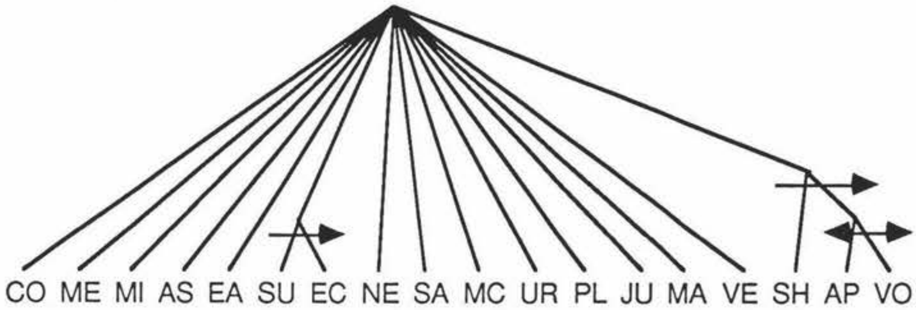

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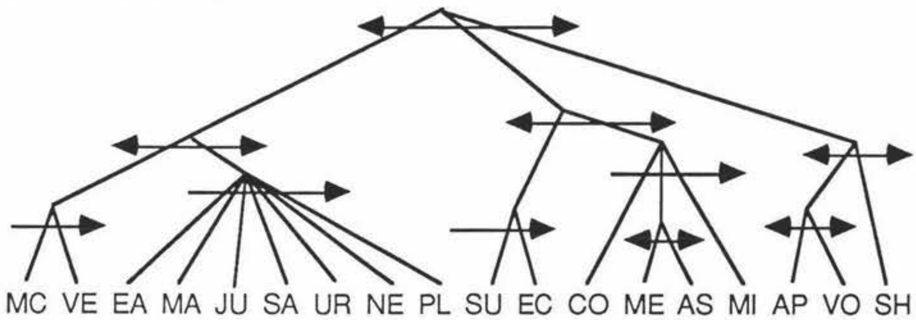

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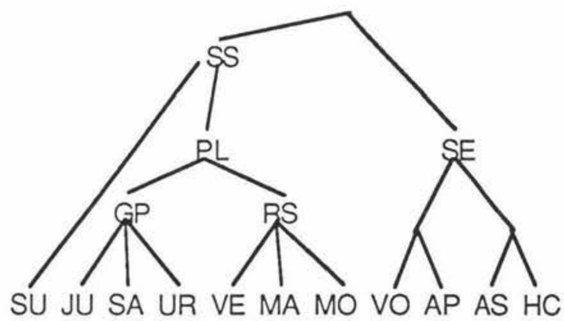

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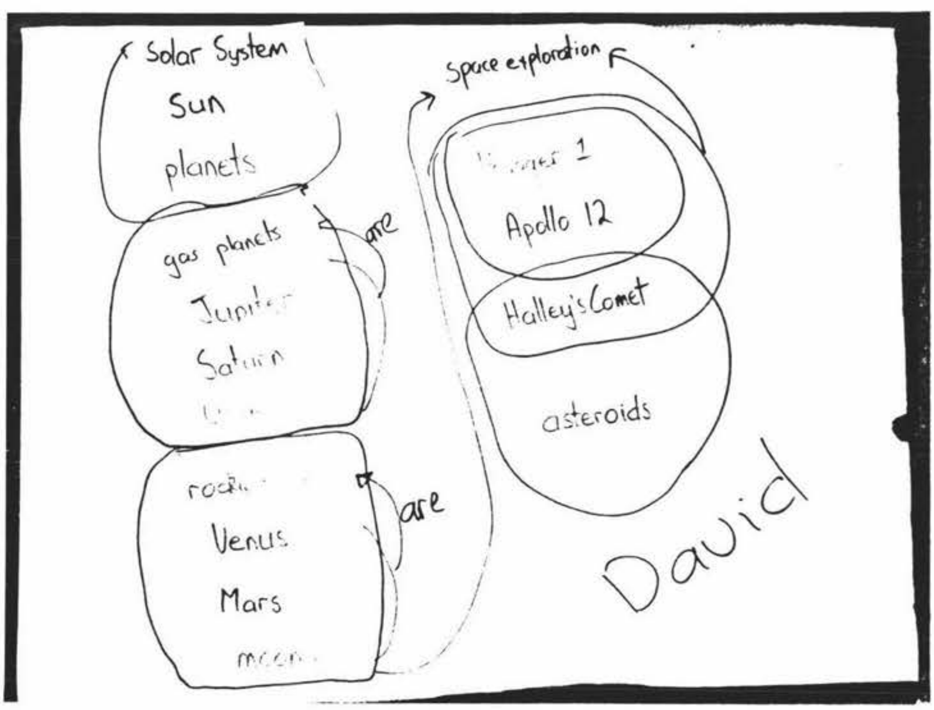

Word processing student

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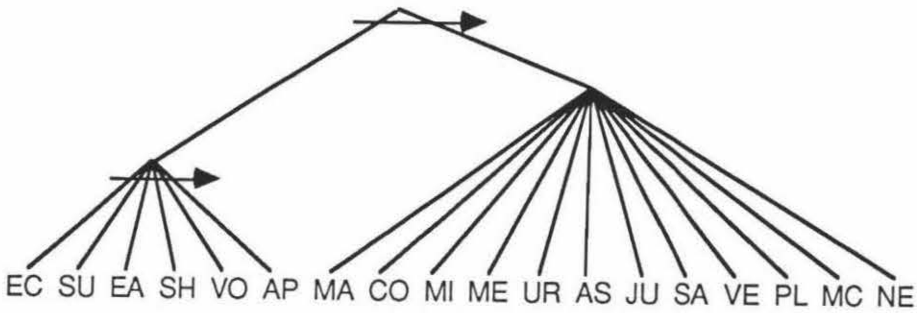

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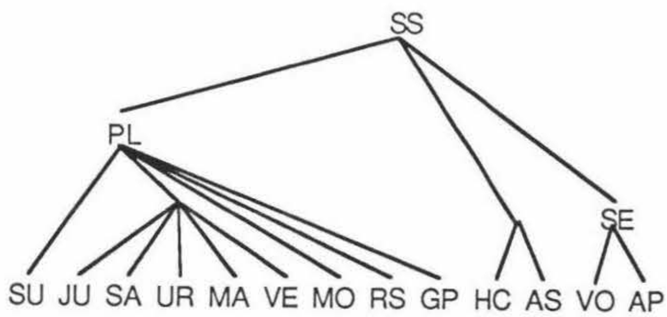

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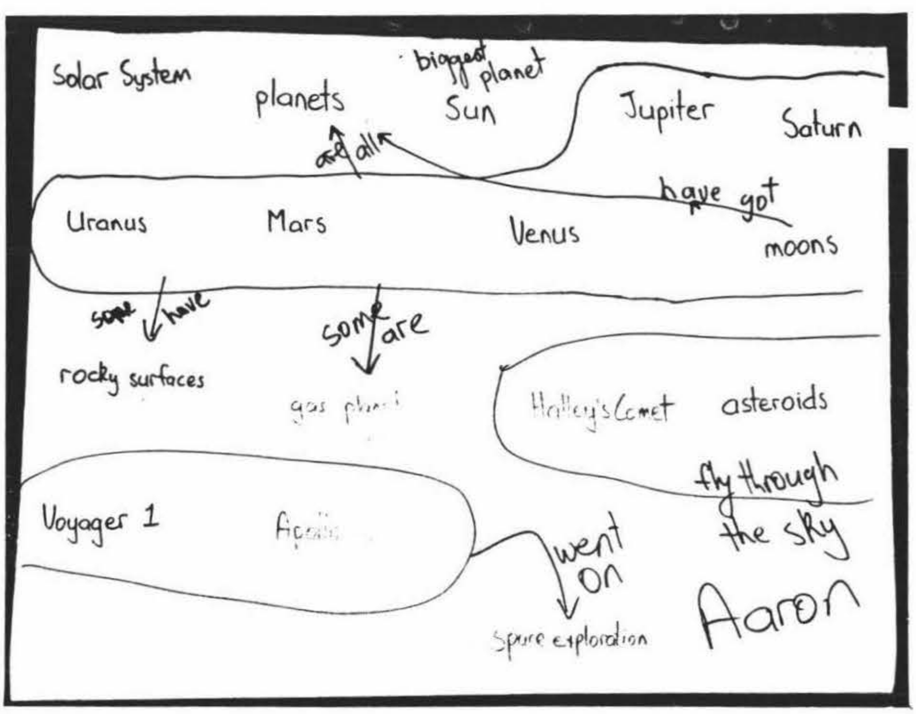

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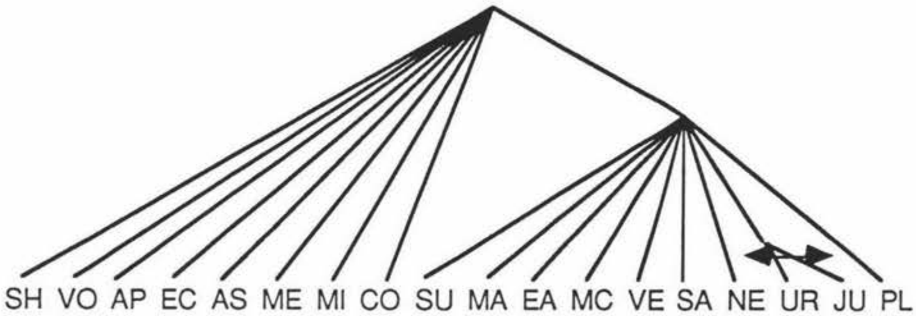

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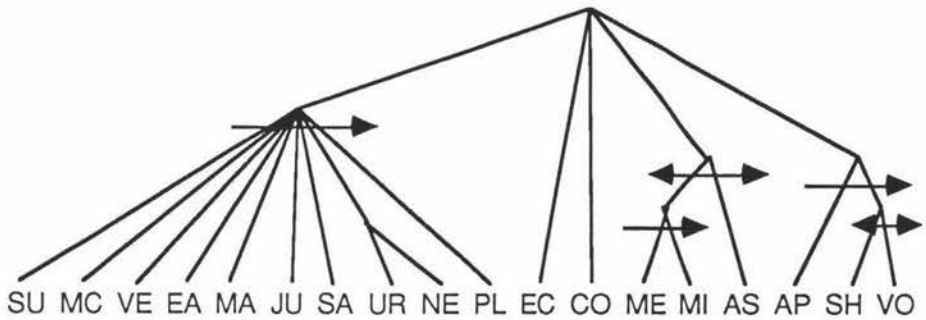

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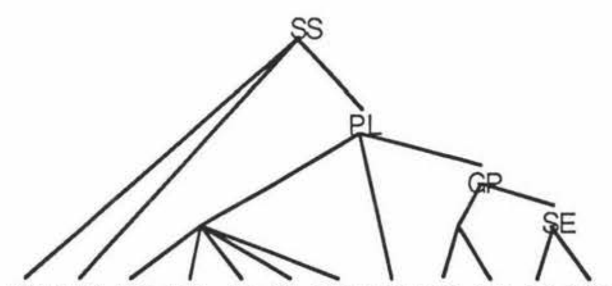

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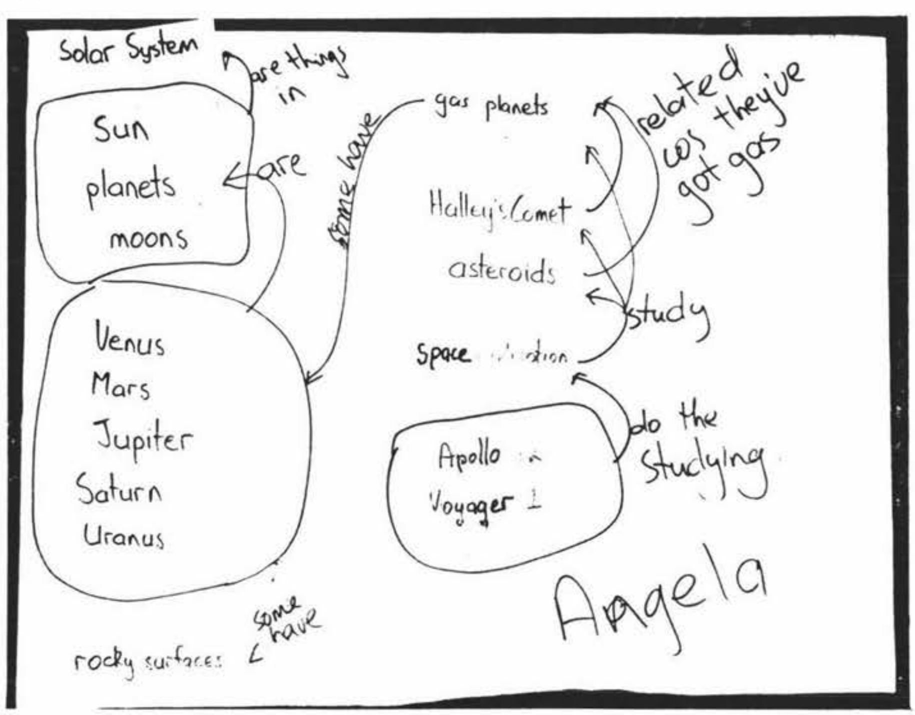

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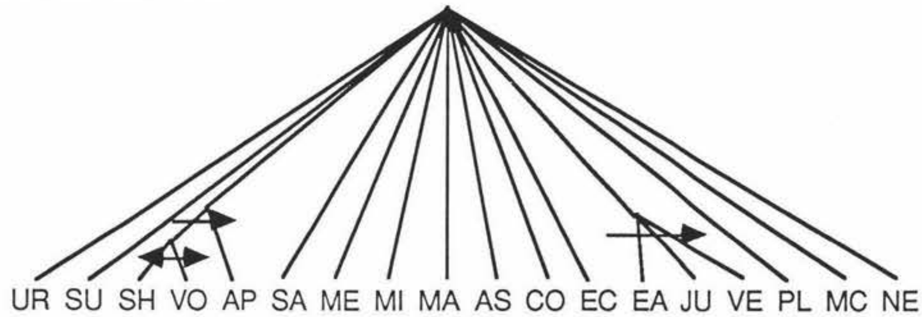

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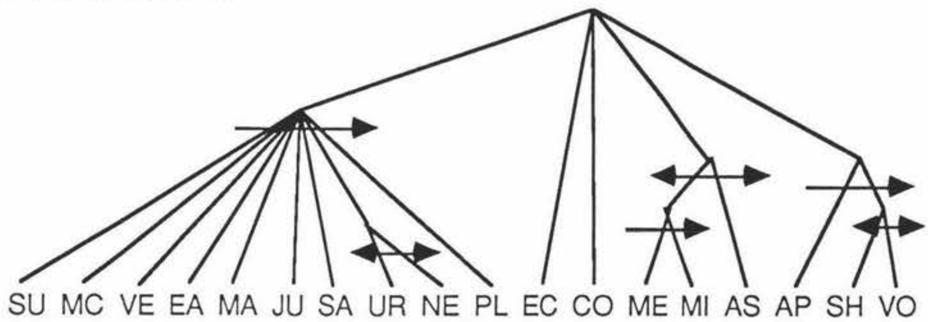

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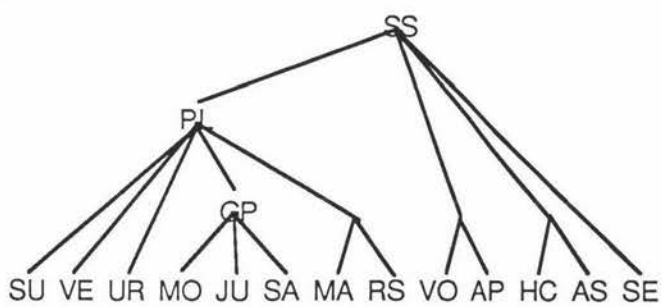

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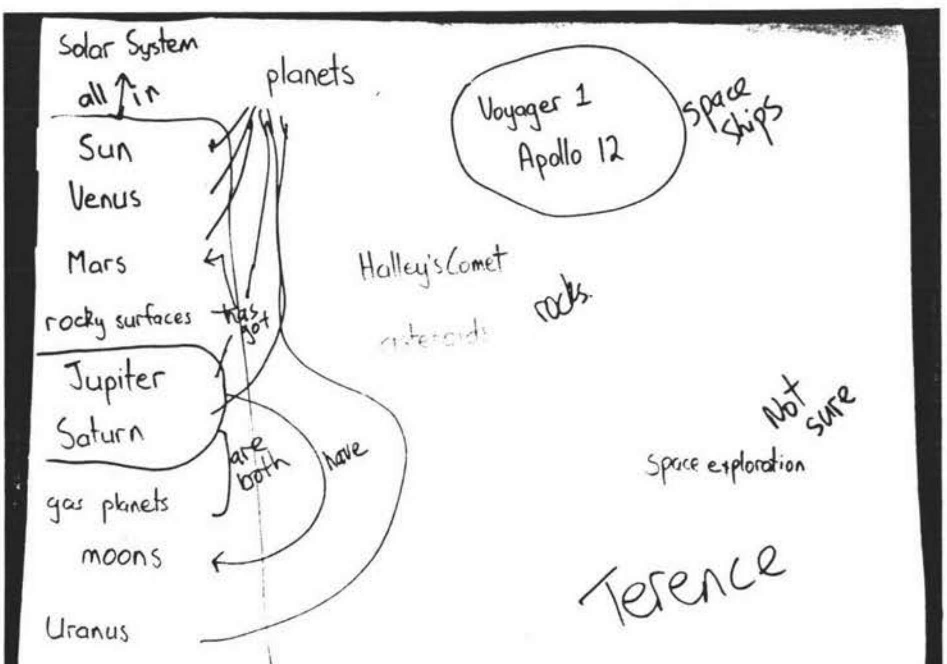

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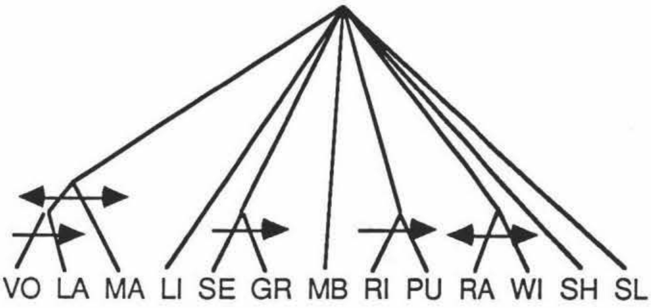

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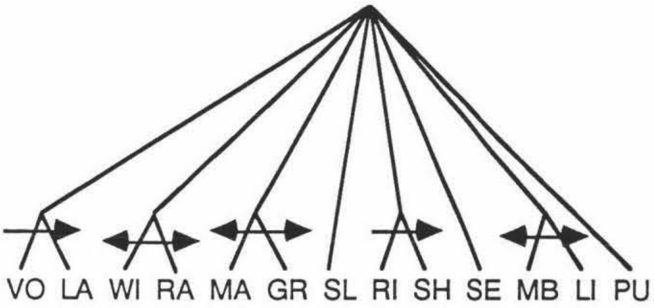

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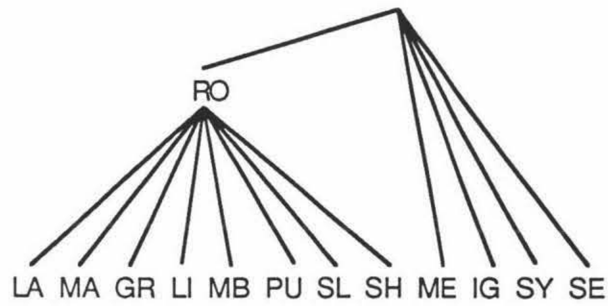

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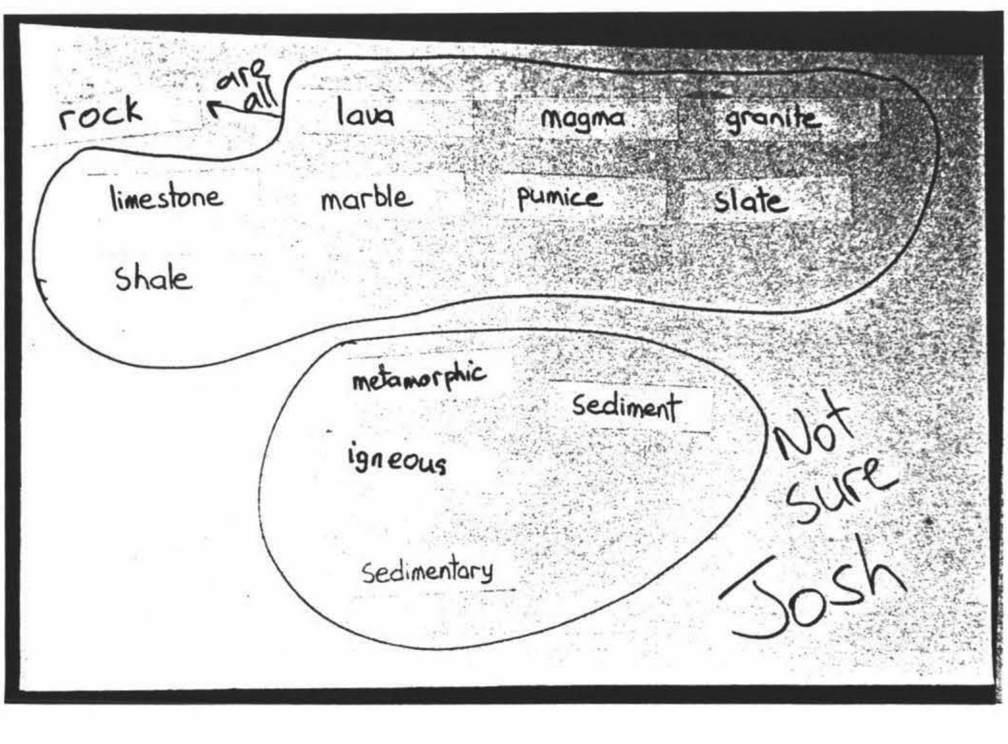

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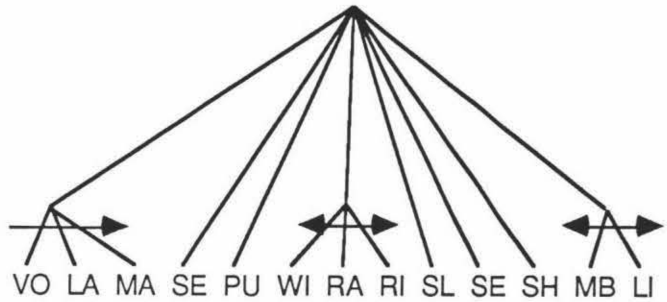

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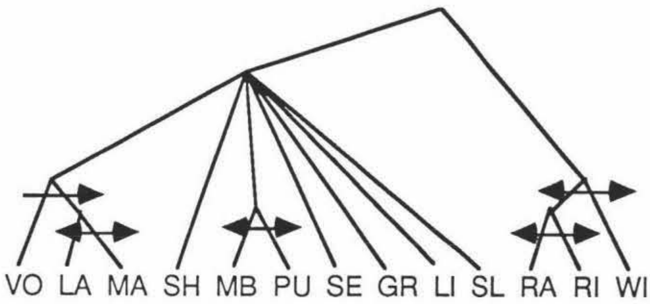

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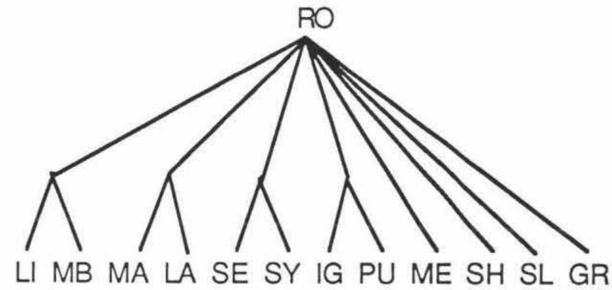

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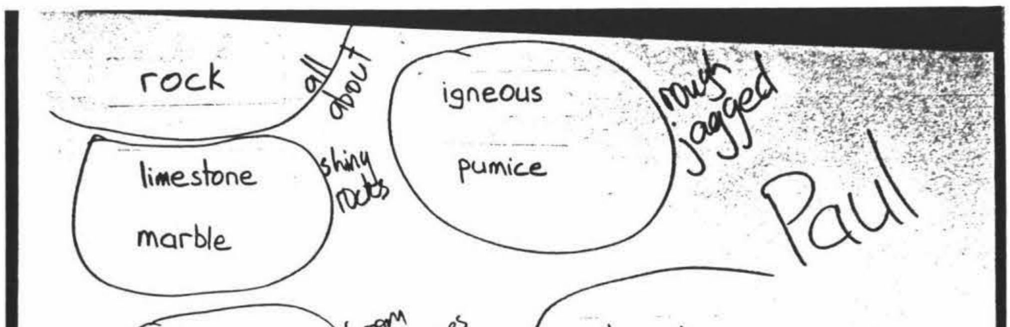

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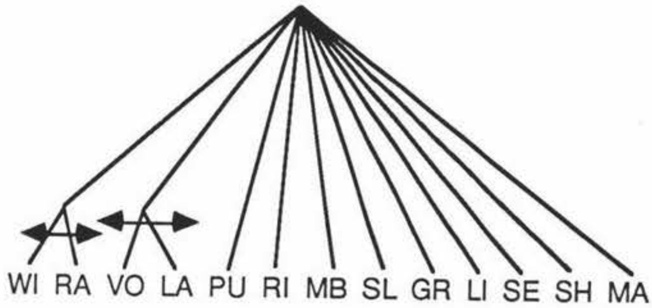

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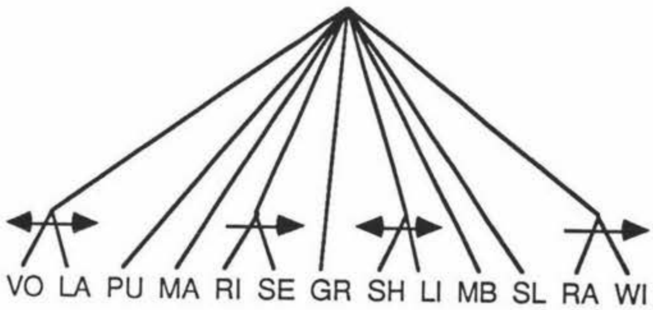

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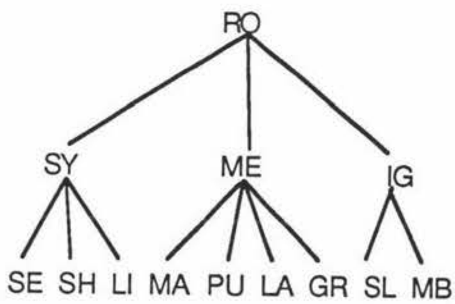

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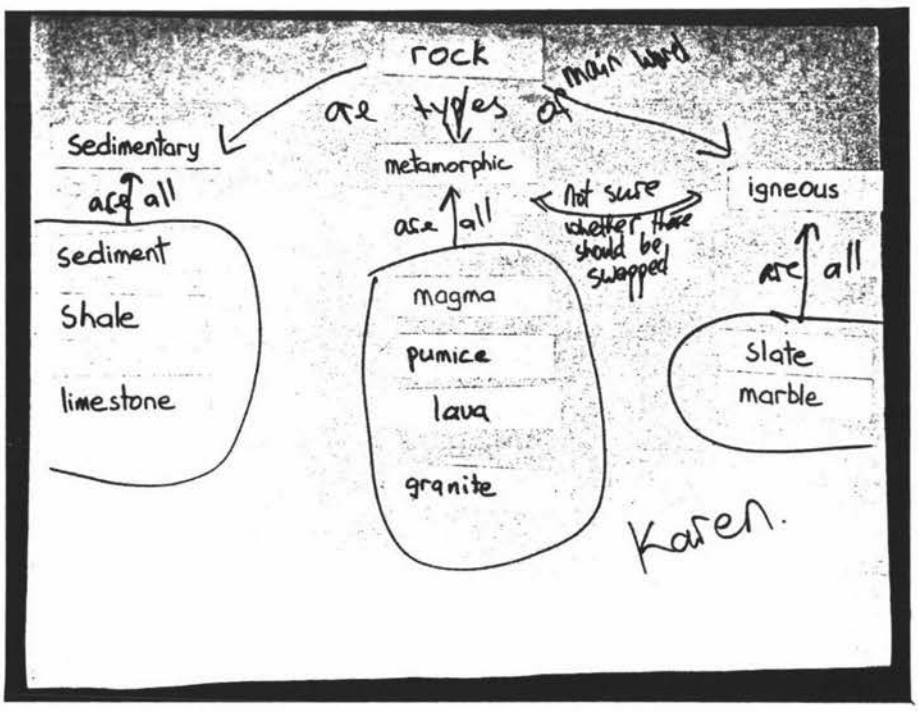

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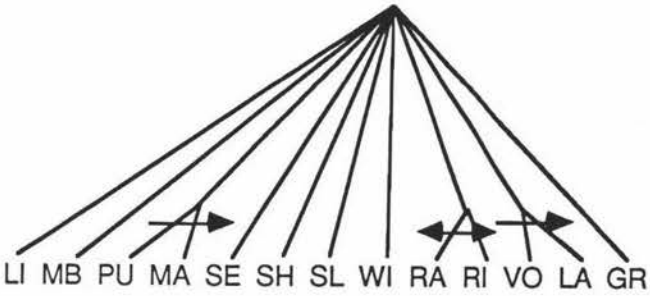

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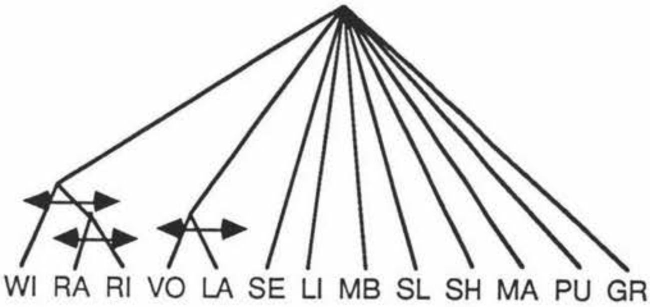

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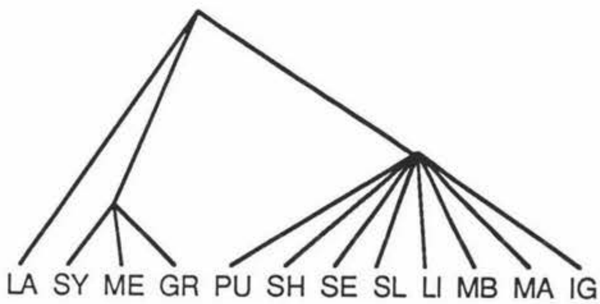

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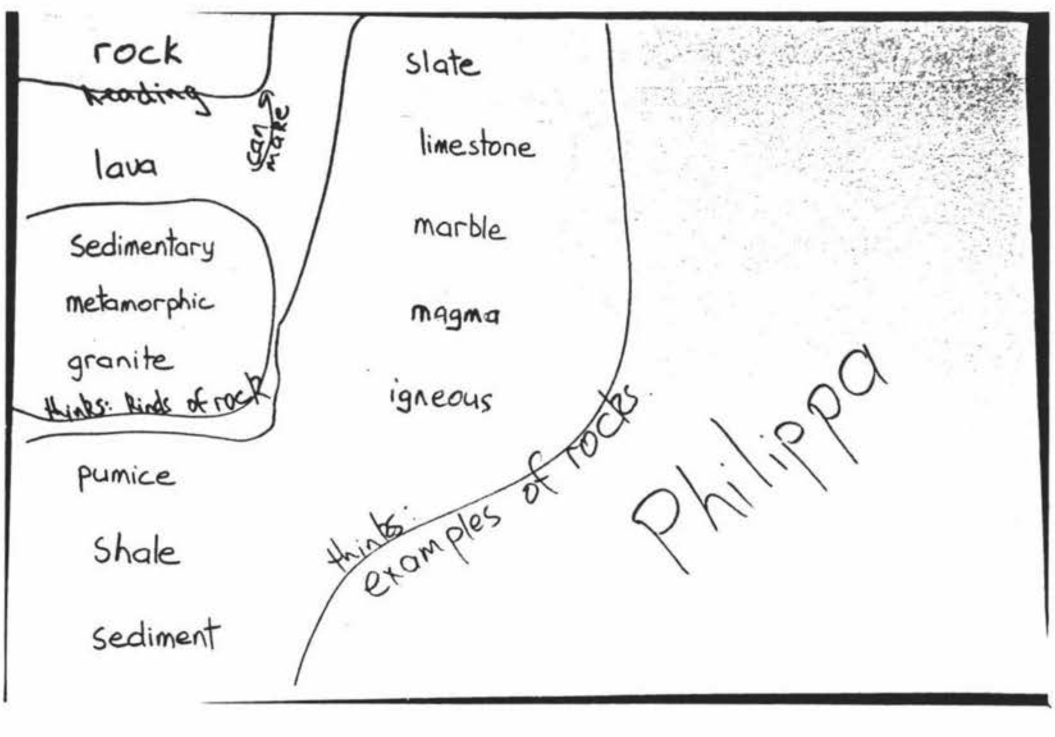

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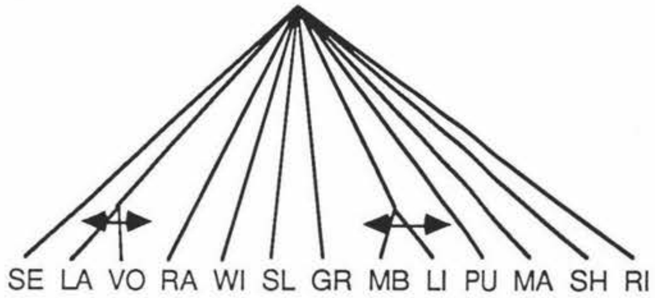

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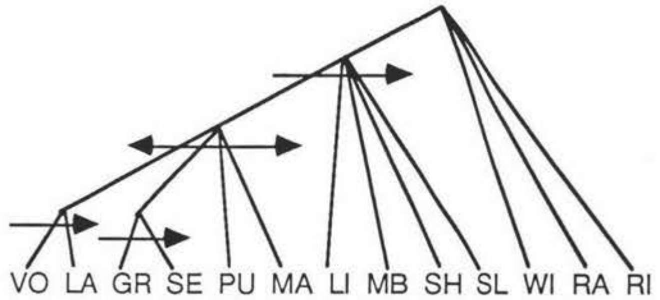

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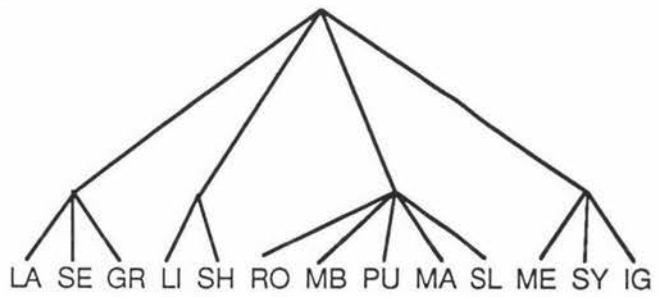

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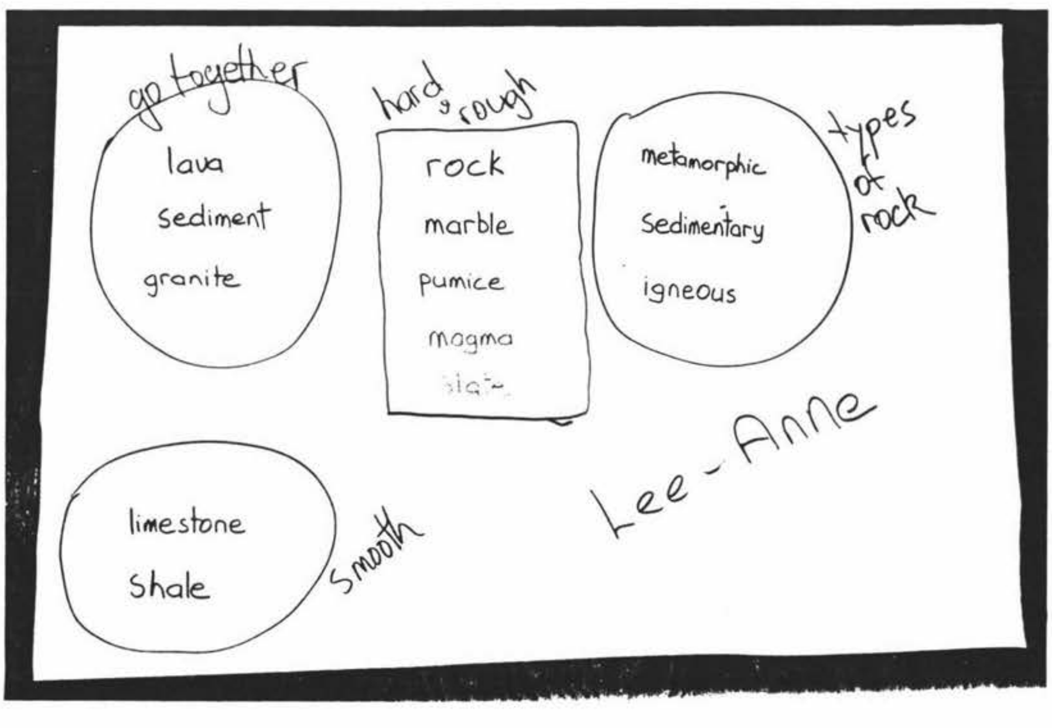

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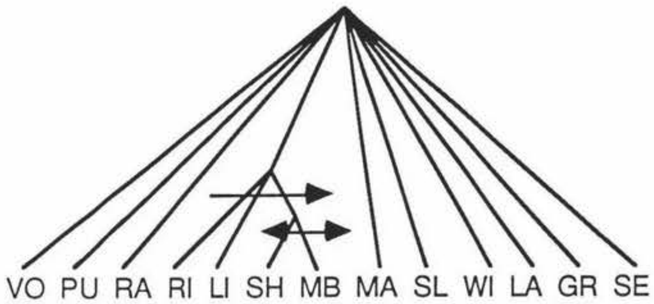

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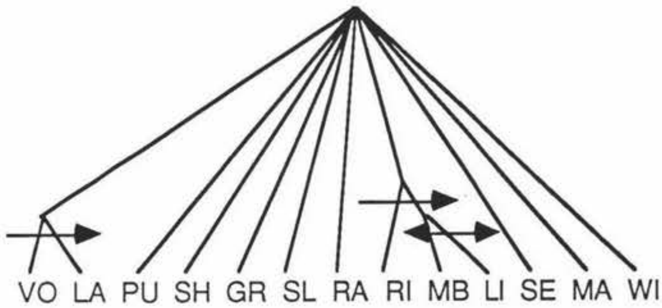

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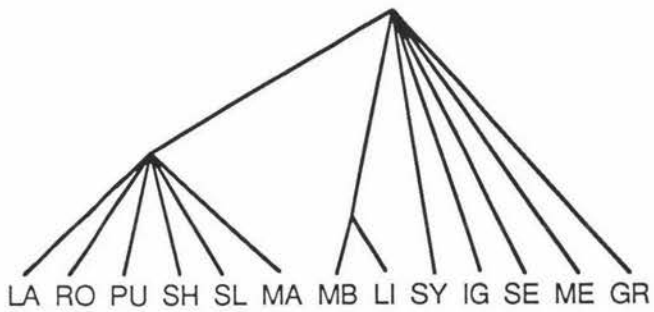

ConSAT diagram