THE EFFECTIVENESS OF COMPUTER BASED LEARNING

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Thesis submitted to the University of Nottingham

for the degree of Doctor of Philosophy

April 1987

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ACKNOWLEDGEMENTS

I would like to thank a number of people for their help and support during the production of this thesis.

Dr. Geoffrey Underwood not only gave moral support, he also provided much needed critical advice on experimental design without which Clark's criticisms might have rung true. I must also thank him for the loan of his very friendly Apple Macintosh!

The analysis of the attitudinal survey could not have been completed without the help of Mr. T. Dolan and other members of staff in the School of Education. Professor D. Wood provided valuable comments on the case study data and Dr. M. Burton was always available to give statistical advice. Miss S.A. Oakley did much work on my split infinitives.

The empirical and case study work presented here took me into a large number of schools. I would like to thank all the staff and pupils who have been involved in this project. In particular, I would like to thank Mr. Judson and all at the John Clifford School, Beeston. They bore the brunt of the work.

Finally I would like to thank Mr. H. Smith, who gave me the opportunity to complete this work, by agreeing to be my Supervisor.

ABSTRACT

Is the innovation of educational computing likely to be effective in facilitating the development of children's minds? The research reported in this thesis approached the question by investigating two issues related to the introduction of classroom computers. Firstly, is the educational environment receptive to the new technology, and secondly, can computer-based learning make significant changes in the development of children's cognitive ability?

The study of attitudes to educational computing was conducted using questionnaire techniques over a three year period, sampling more than 300 teachers and teachers-in-training. There were two main goals: to measure and compare the attitudes of serving teachers and teachers-in-training, and to identify factors influencing the development of these attitudes. Four main attitudinal groups were identified by a cluster analysis, with more positive than negative statements being made, in general. Positive attitudes revolved around the potential of the computer to promote more child-centred learning, and around its usefulness across a wide spectrum of the curriculum.

The investigations of the role of the computer in developing children's minds, conducted using experimental and case study techniques, also had two main strands. A series of experiments determined the children's knowledge of the ways in which data can be organised, a pre-requisite for the use of classroom data-bases. The experiments suggested that junior school children should be able to use two-dimensional data structures even though they might have difficulty in constructing them. The second strand in these investigations was to observe the effects of the use of of computer data-bases upon classificatory ability. Using pre-test/

post-test comparisons, children were found to benefit from the use of proprietary software in that their logical thought improved. The detailed observation of eighteen case studies confirmed the usefulness of data-bases in the development of children's thinking.

The study, by using a number of research techniques, has demonstrated that the educational community is prepared to accept the innovation of classroom computers, and that significant cognitive gains will accrue by doing so.

SECTION ONE: ISSUES

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CHAPTER 1

ISSUES IN EDUCATIONAL COMPUTER USE

"Technological change continues at an accelerating rate, in the short term possibly compounding our economic and social difficulties and in the long term providing better solutions. The process of education will continue to be influenced by the explosive effects of micro-miniaturisation on the technology of communication, computation and information storage and processing" (Issues and Directions. The Ontario Ministry of Education, Ministry of Colleges and Universities, 1980, p.12)

1.1 Introduction

How effective is the computer as an aid to classroom learning? Does it add a new dimension to the learning environment or simply parallel established classroom practice? Indeed is it of any benefit at all? The impact on children's cognitive development of using computers as a learning tool is the core issue addressed in this thesis.

This introductory chapter will consider some of the educational issues which are highlighted by, and in some instances created by, the introduction of computers into the classroom. The computer is a powerful instrument which may be used to stimulate and support many disparate educations, but which mode of education should we choose? This is a critical question, for the choices we make about the use of the computer may have profound effects, not only upon the nature of education itself, but also upon the development of children's minds.

The work reported in this thesis questions the effect upon children's thinking of the use of the computer as a tool. The experimental investigations are directed towards a study of the child's ability to organise and use information, and the development of that powerful cognitive skill, the ability to categorise data. As an adjunct to this main theme, the study also considers the role of the teacher as curriculum innovator, a key person in the successful implementation of curriculum change.

1.2 The Growth of Educational Computing

Amarel (1983) suggests that there are two ways in which the computer will have an effect on education. In the first place it can be an aid to learning and instruction in the classroom, and in the second place it can act as a research tool shedding light on human cognition, providing the input to future learning theory. The research impacts have yet to filter into the schools, although work such as Berwick's (1985) simulation of the acquisition of language could do so in the future; and evidence of the effect of computer-usage on learning and teaching is only now being gathered as in this thesis. There has been a more immediate and obvious impact of computers in schools, however, in that we now have a new subject-area in the secondary curriculum.

Although computers entered our schools in the 1960s their use was restricted to a small group of dedicated teachers and selected children. Not until the late 1970s, in the case of secondary schools, or the mid-1980s, for primary, did classroom computer use become widespread. Early use in the secondary school tended to be either as a study of the computer itself, including programming, or for mathematical investigations. There is a clear dichotomy of use here. The computer initially was the object of study itself, either through 'awareness' and 'literacy' courses or through computer science/study courses, or an instructional tool in mathematics. This latter use has now spread through a range of curricula areas.

The rise of computer studies, and related courses, is no trivial matter for it can have profound effects on education. The place of such studies on the timetable has been justified in a number of ways. In particular, two well-worn arguments have been put forward. The first is the need for societal and vocational relevance, a theme certainly in the minds of the present government. The second argument revolves round the teaching of programming. Here it is asserted that introducing children to programming will result in a new way of thinking, and that the child will become a formal reasoner of some power (Papert, 1981; O'Shea and Self, 1983). This is the age-old argument for the relevance of the Classics in the education of Whitehall mandarins. Programming, it can be argued, is the new Latin.

Such arguments highlight the dilemmas of the school curriculum. The introduction of a new subject results in pressure on all other curricula areas. If a high value is placed on one area through the allocation of resources for materials and staff training or promotions, then pupils will gravitate to those subjects and other areas may be starved of time, resources and the most able students. Thus the average or less gifted student may be unable to gain access to the prestigeous knowledge and other subject areas may be unable to gain access to resources. In the case of computer-usage this has resulted in a stifling of computer use across the curriculum, and currently many secondary school pupils, having been keen computer users in their primary schools, have no access to the machine in their new schools (Smith and Keep, 1986).

This thesis is not concerned with "doing computers" in that I shall not be discussing the growth and relevance of computer 'awareness' or computer studies courses in the schools. The studies presented here are all concerned with the use of the computer as an instructional tool within the school curriculum. This delimitation of this study's boundaries must, of necessity, be regarded as 'fuzzy.' Often activities in the classroom which appear to be concentrating on using the computer as an instructional tool are in reality geared to giving children 'hands-on' experience with the computer. In my own experience, attempts to persuade primary schools to change the organisation of computer use from the one day a week for each class format to block usage, to enable children to develop data bases, word processing or complete a simulation project, often founder on the belief that parents will not accept such a re-organisation. Teachers argue that parents value their child's contact with the computer and feel that it is necessary for him or her to have the opportunity of five minutes' regular keyboard experience as though it were a panacea for a number of ills, particularly that of unemployment!

This subjective impression that 'awareness' goals for classroom computer use are seen as important is confirmed by an analysis of teachers' aims for using the computer outlined in Chapters 3 and 7 of this thesis. Further evidence comes from the Ontario Government's "Microcomputers in the Classroom" project conducted by Eaton and Olson (1986) in eight elementary schools. Although not all the teachers used the computer for 'awareness,' those that did argued that it was important to prepare children for the computer society of the future. Their method of preparing their students was to get the children to use the computer frequently but for short periods of time. As the teacher would be conducting the 'normal' class activities at the same time, the computer children, usually two at a time, had to be independent and make no demands on the teacher. The teachers, therefore, selected small, stand-alone programs often of drill and practice format, but which were 'idiot proof' and 'user friendly.' The use of packages such as LOGO was not seen as practicable.

Eaton and Olson record a second finding which most of us working in this field can readily confirm, that the computer was used as a reward. Well behaved children were given extra turns on the machine but those who misbehaved lost their turn in the rota. In this way the computer can be reduced to an extrinsic reward, the up-to-date version of the gold stars or bars of chocolate which are still visible in many schools today.

At the outset, then, it should be noted that teachers' statements that they are using the computer to develop language or mathematics skills may hide a range of other educational goals. Eaton and Olson's teachers, although initially aiming to provide experience of the machine (over an unspecified period of time), developed new goals related to motivation and a desire to change the social structure of the classroom. Simple observation of classroom activities tell us what goal lies behind any one activity. Eaton and Olson's teachers used programs in standard curricula areas but their articulated goals were to give keyboard practice and reduce adverse feelings toward the machine through familiarity.

These problems, and others, associated with conducting research in the classroom will be examined more fully in Chapter 2. Here I will consider some of the educational issues which have arisen from the introduction of computers into the classroom and outline the main aims of the thesis.

1.3 The Technology Bandwagon

Twenty years ago Patrick Suppes (1966) argued that developments in educational technology, and specifically in computer usage, would change the face of education in a very short space of time. He based this prophecy on the unique capabilities of the computer to be used interactively, to present materials in novel ways not easily available through other media, and on the flexibility of the machine in adapting to different learning and teaching styles. In making his predictions he was drawing on a long history of educational innovation. For example, the printing of the Gutenburg Bible revolutionised education as the printed word became the focus of instruction, replacing the oral tradition of popular knowledge transmission.

There is evidence of a significant impact of micro-technology in some areas of our educational system. Already the computer plays an important part in communication in many higher educational establishments, through the use of text and information processing packages, as well as electronic mailing systems such as the Universities JANET (Joint Academic Net) system. Academic researchers, in particular, in both the Arts and the Sciences have responded to the benefits that micro-technology can bring. The school system is not immune to the march of technology, either. It too has its own national/international communication system TTNS (The Times Network for Schools). In my own county of Derbyshire all colleges and secondary schools are now linked to this system and currently primary and special schools are being given the opportunity to join the network.

This is not to say that the computer will replace the book or the written memorandum. They will survive, just as handwriting and the oral story tradition survived print. However there are people who doubt this; for example Goff (1984), who made an impassioned plea for the retention of the book into the year 2000, at the the United Kingdom Reading Association's conference entitled "Reading and the New Technologies." Moreover, the very title of Harrison's (1981) paper: "The textbook as an endangered species: the implications of economic decline and technological advance on the place of reading in learning." indicates current concern, although Harrison does sound a cautious note of optimism at the end of his paper by expressing the belief that continued existence of the book is not ultimately in doubt.

1.4 The Powerful Computer

> "Computers call up strong feelings, even for those who are not in direct contact with them. People sense the presence of something new and exciting. But they fear the machine as powerful and threatening" (Turkle, 1984, p.3).

The hopes and fears associated with this particular technological innovation may seem extravagant. Why does the computer generate such powerful feelings and expectations? Our environments - the home, the workplace and the school - are already full of machines which sit unobtrusively in the background of our awareness unless something goes wrong with them. Why should we view the computer as being different? Ihde (1975) describes man-machine relationships in terms of their degree of transparency or opacity, defined by the extent to which the machine becomes an extension of the human user or remains as another-self, a significant other. Ihde argues that there are three levels (types) of interaction between the human user and the machine. The first level occurs when the human is using an implement such as a pencil or a car, in which the machine becomes transparent; that is it becomes an extension of the user's own body and the user can feel the environment, the roughness of the paper or of the road surface, directly through the machine. When using a telephone or watching the television, this direct tactile experience is lost, and a level of translucency is reached as the machine still extends the individual's hearing or perceptions although the experience of the caller on the other end of the line, or the tropical island on the screen, is in a reduced form. In both these types of interaction the machine disappears into the background.

In the third type of relationship this extension of bodily experience is lost, the machine becomes opaque and separate from the user. "In some cases relationships may actually be with machines. Here is a conversation with the machine and the 'user' and the machine emerges as a quasi-other" (Ihde, 1975, p.196). Ihde argues that the computer functions at this third level of opacity and is, therefore, fundamentally different from most other machines in our lives. It is now in the foreground impinging on our awareness; the mechanical aspects become subsidiary and the focal relationship is between the user and the quasi-other person. This personalisation encourages us to discuss the 'user-friendliness' of the machine.

Turkle (1984) expresses the essential difference between computers and other machines in terms of their marginal status. She argues that they are objects on the borderline living/not living categories: "A new kind of object - psychological, yet a thing." (p20). Her anecdotal evidence confirms this feeling that computers are different. For example, she discusses the holding-power of the computer and the degree of parental concern, even fear, that is aroused by their children's obsession with video-games. She also recounts instances of adults who are equally vulnerable to the fascination of this machine.

It must be noted that humans do not only communicate, but they are also transformed by their communications. What is important for us to understand as educators is that the computer is not neutral, it will exert an active influence on the learner; an influence which we should monitor and evaluate.

1.5 Issues of Educational Computer Use

1.5.1 Resources

By the beginning of 1984 80% of secondary schools had some level of computing provision (Wood, 1984), and the active acquisition of hardware gained momentum with the help of both national and local government funding. Provision in the primary sector has also moved on apace. In 1980 only thirty primary schools in England were using computers (Jones, 1980). Four years later Jackson, Fletcher and Messer (1986), in a 1984 survey of Hertfordshire schools, found that 56% of establishments had at least one computer and 24% were waiting for a machine to arrive. By 1985 this had increased to 94% of schools with at least one machine, according to Bleach's (1986) representative sample of U.K. primary schools. Of the 6% of schools still without a computer, 15% were awaiting the arrival of a machine.

Bleach found that many primary schools (58%), particularly infant or first schools, had purchased only one computer. The vast majority of schools (86%) had taken advantage of the Department of Trade and Industry's introductory scheme. The ratio of children to computers varied enormousely. At its worst one school shared a computer between 450 pupils, but over 65% of schools had one computer for every 150 pupils or less and in 21% of establishments this ratio was 1 to 50 or less. This pattern of extremely broad penetration, but without a concentration of resources, is parallelled in the USA (Goor, Melmed and Ferris, 1981) and Ontario, Canada (Eaton and Olson, 1986).

More disturbing than the overall machine-to-school or machine-to-pupil ratios was Bleach's discovery of the lack of peripherals to machines; only 25% of schools had a printer and only 9% had purchased a concept keyboard, which many people (e.g. Straker, 1986) consider to be a vital piece of equipment for effective work with the youngest or the less able children. The lack of printers is not surprising. The DTI has shown that it does not see the relevance of this piece of equipment in primary schools by failing to extend its secondary printer offer into this sector and, as Bleach has shown, they have profound effects on purchasing policy in the primary sector. Yet Smith and Keep (1986) in their survey of children's opinions of educational software, found that the use of word processing systems was almost universally popular with those children who mentioned it. The children found the experience of developing, manipulating and reproducing text to a professional standard to be a very satisfying experience.

An interesting aside might be commented on here. Smith and Keep found no sex differences in the response to word processing, boys and girls were equally positive. However, all of the girls expressed concern over the de-skilling of the typist/secretary's craft and commented on the potential closure of traditional slot in the job market for their sex. As Smith and Keep suggest, this may be a reflection of parental attitudes and concerns possibly stemming from experiences in the current job market.

Chambers and Sprecher (1980) suggest that the single most critical issue today in computer based learning (CBL) is the development and sharing of quality software. Indeed the lack of good software is frequently cited by teachers as a reason for their reluctance to incorporate CBL techniques into their own classroom practice (Reid and Shields, 1985; Bliss, Chandra and Cox, 1986). Now that many, although not all, of the initial technical and economic problems of computers in education have been resolved with the advent of cheaper and increasingly reliable microcomputer systems plus substantial funding from national government, this emphasis on software is understandable. However, the questions arising out of the spread of new technologies into the classroom are not just issues of how to put traditional lessons onto the machine in an efficient and economical manner, although much of the current research is directed towards that end (e.g. Alderman and Mahler, 1977; Kearsley, 1985).

1.5.2 Usage: possibilites and probabilities

Despite this massive injection of resources, however, the impact of the technology appears to be minimal. Education appears to have changed very little and it might be argued that the worries, reported earlier, of Goff and Harrison about the demise of the book in the technological classroom, are groundless. This lack of change is underscored by Bleach's (1986) report. She found that, in general, computers were underused; for 58% of her survey schools the machines were in operation for less than 60% of available time, while a significant minority, 20% of schools, used this costly resource for less than 20% of the available time. Although figures are not available, personal experience would suggest that by implication the computer is in far less demand than that other technological innovation in the classroom, the television! As Anita Straker (1986) expressed it, the classroom computer use is, in general, "A sorry state of affairs" (TES, 1986, pp. 30).

Although Jackson et al. (1986) present a generally rosy picture of enthusiastic teachers willing to use the new technology, they too report a very low-level of impact. The main change reported by their teachers, following the introduction of the computer into their classroom, was the need to re-arrange the furniture to accommodate the machine (43%). Only 25% reported changes in their style of teaching when the computer was in use and 28% reported a change in timetabling.

We should not be too critical of these teachers, however, for the organisational problems of computer-usage are very real. The computer may be seen as enriching the learning environment, but at the same time it is a scarce resource which teachers must allocate. As we have already noted, such allocation is often on a principle of natural justice, fair shares for all, unless the child behaves in such a way as to warrant withdrawal of the privilege, even if that prevents the use of exciting materials such as LOGO. Teachers must also decide on how much of their time can be spent on supporting computer activities and at what cost to other curricula areas. Eaton and Olson's (1986) teachers decided that the cost must be minimal, although they did articulate the need for guidelines from their school inspectorate.

There is a paradox here - on the one hand it can be argued that there are too few machines in the classroom and on the other hand research, such as that of Bleach and Jackson et al., point to an under-utilisation of the resource. Part of the explanation of this apparent contradiction lies in the conflict between hands-on experience and the tool-use of the computer. If children are to use the computer in ways other than a drill and practice machine, then they need ready access to the machine for a block of time, and this will necessarily result in some children having to forgo their computer time. If a principle of fair shares for all governs the way in which the computer is used then more time-demanding packages can not be used, and the computer is reduced to a practice machine or a simple reward system. Teachers are unimpressed by such applications, which are often seen as a trivialisation of education, and they may well feel little incentive to use the computer which , as all nine-day-wonders, is gradually relegated to the corridor or to the back of the cupboard.

Our educational system today is still a product of the Gutenberg-inspired print ethic and the goals and values of our schools have been devised to instruct pupils to function in the print environment. This may be considered as one of the reasons for the non-fulfillment of Suppes's (1966) prophecy, but there are others. In particular, workers in education, blinded by the technology, often have high expectations which they find are unfulfilled, when they belatedly evaluate the quality of the learning experience. Richard Clark (1984) points out that we are continually searching for new technologies that will result in increased learning outcomes in comparison to 'older' media, and that the computer is seen as a particularly powerful technology in this sense. For example, consider the claims made by Mersich (1982) who argues that, within the North American setting, advances in computer-based learning (CBL) will soon make it possible for private enterprise to compete with the public education system as long as the laws on school attendance are relaxed. He further predicts that this privatised educational system will flourish in comparison to the state system which it will "whip in quality, and make a profit at the same time." (p. 37) . A similar belief in the value of the technology was expressed by Franks (1984) and by the BBC, in its 1983-1984 advertising literature, which posed the question, "Will your children go to school?" Both Franks and the BBC suggest that the computer could take over the traditional role of the school in transmitting knowledge, leaving the schools to fulfill the role of socialising children and developing their physical skills.

Clark questions the teaching role of the computer in education, however, arguing that it is very easy to mistake sophisticated technology for sophisticated learning, assuming productive outcomes will emerge when students communicate with computers. There are indeed many examples of complex technology being used to achieve low-level educational goals.

The National Science Foundation of America's Time-shared Interactive Computer Controlled Information Television project, TICCIT for short, (Bunderson, 1974) and the current development of distance learning (Freeman, 1984) are two cases in point. In these projects the machine is used for the largely didactic transmission of knowledge from 'teacher' to 'learner,' and subsequent testing of the learner's acquired knowledge base. Although such programs often contain sophisticated models of concepts and operations within a subject domain, they have no knowledge of the students. The machine delivers the information to the students and they must then attempt to interpret and assimilate that information into their existing knowledge structure.

The computer is a very versatile machine, however, which can be used to promote more sophisticated learning strategies in which the machine or the student, or both, take a more active part in the learning experience. It is this very versatility which raises fundamental issues about the future direction of education both in the U.K. and elsewhere. The computer can be used to great effect as a calculator, a 'teaching' machine, a processor of complex information and a creator of microworlds. In essence this means that the computer can support the full spectrum of educational philosophies: for example acting as a tutor for those who believe we should return to a basic skills curriculum or as a key factor in stimulating the dynamic process of writing.

Dede (1986) suggests that instructional control strategies for educational computer use form a continuum based on the balance between the varying levels of passivity of the computer and the child. At one end lies the directed learning strategy in which the student is a passive recipient of wisdom unable to explore the material. At the other end the open-ended problem-solving computer based tools such as LOGO, data-bases or a word processing package. Such programs give control to the learner but no longer provide guidance when the student is stuck, although they may inform the child that an error has been made or an inappropriate action taken, as in LOGO or in the use of data bases. Of course , in word processing, the computer may not necessarily provide even this rudimentary feedback. Put very crudely, one end of this continuum will appeal to those teachers who believe that there is a critical public corpus of existing pre-knowledge which all students need to be taught and to know, while at the other end are the teachers who believe in the need for the child to discover his or her own truths with varying degrees of support from the teacher.

In the centre of this continuum are the new breed of programs in which control can shift from student to machine as necessary, such as O'Shea's quadratic tutor (1982), which are founded on approaches to teaching and learning such as Bruner's (1978) principle of scaffolding. These intelligent computer-aided instruction (ICAI) programs are the key, for many people, to the new education where knowledge is machine transmitted and the foundation for the belief that the computer will de-humanise education. Although Dede (1986) argues a very cogent case for such software two points should be raised. On a pragmatic note we have yet to see an ICAI program which can fulfill the role of 'coach' as Dede describes it. The programs to date are still very much content rather than process driven. Secondly in denegrating the open-ended tool usage of the computer on the grounds that it does not support the child with individualised feedback, Dede has failed to understand that a different type of learning is taking place to that of the acquisition of facts or even concepts. In such programs children are not capturing past perceived wisdoms, rather they are honing their own thinking skills.

The question to be resolved is, how do we select the path to take when the computer offers such a range of instructional and learning strategies, and once we have selected the pathway what do we need to do to ensure that our educational goals are reached? These are crucial questions for education as a whole, both across the curriculum and across the age-ranges.

The debate concerning the most profitable ways in which we can use this costly and, in some schools, scarce resource, can simplistically be reduced into that of the computer as 'teacher' (the sub-skills tutoring/practice approach) versus the computer as tool, given the absence of ICAI packages at present. The most easily identified uses of the computer as a tool are those seen in operation in the world outside the classroom, namely data processing and word processing. At the moment, it is apparent that the practice of basic skills dominates the educational use of the computer, a fact which leads Chandler (1984) to suggest that this machine has made it possible for educational practice to take a giant step backwards into the nineteenth century! Rubin (1983) echoes the complaint that there is a concentration on the development of low-level skills in reading and language. He argues that this is due in part to the nature of the computer, which encourages a mechanistic, detail-oriented education, focusing on 'correct' or un-ambiguous answers; but also to the ease with which work cards and books, concentrating on sub-skills, are converted into programs.

Indeed, the most disturbing aspect of Bleach's (1986) report is the findings on the nature of computer usage. Drill and practice and learning reinforcement programs, concentrating on low level cognitive skills of spelling or word recognition, predominated in these classrooms, with far fewer schools using their machines to stimulate higher cognitive skills such as story logic. These findings concur with other surveys in Britain (Jackson et al., 1986) and in the United States (Becker, 1982).

The use of drill and practice software has it s advocates, however. Amarel (1984) considers that the superiority of practice programs is compelling in comparison with the workbooks or sheets that they replace. In well designed programs children can receive quick and accurate feedback, progressing at flexible rates, without public approbation of their errors. The educational computing journals all too often quote from interviews with children, whose main motivation for wanting to use the computer is the patient, kind and generally non-condemning attitude it presents to their follies.

The practice of such skills is not inherently wrong - indeed practice is vital if skills are to reach the level of automaticity necessary to allow the individual to focus attention on higher level problems (Underwood and Underwood, 1986). If sub-skills practice is all there is to education then it is sadly impoverished. Basic sub-skills practice is essential, however, and the use of computer can not only make practice less tedious for all concerned (by building it into a games-format package), but can also make practice less the focus of the activity (by integrating practice with the development of other skills). One of the great benefits of the high capacity machines now available, is the facility of integrating activities at different cognitive levels. The same program may require sub-skills arithmetic practice and three-dimensional navigational mapping, with overall success in the simulation game depending upon success at both levels. For example, relatively simple programs such as Richard Phillips's ERGO or Anita Straker's GUSINTER deal with an understanding of multiples, but they also require the child to use that knowledge in such a way as to solve a more general problem. The user is engaged in sub-skills practice through goal-directed activity. Drill-and-practice is necessary for the development of automatised skills, but it does not have to deal with children as automatons.

Although not yet in a majority, there is a growing percentage of teachers who are using the tool-like capabilities of the computer to show things, to say things or to provoke thought. Jackson et al. (1986) found that teachers who had received at least the minimum two-day In-Set training (DES terminology for in-service training) were significantly less likely to use drill and practice software, than their untrained peers. They could not establish whether this was a result of training or a matter of self-selection, that is teachers who were more interested in innovative approaches to computer use were more likely to volunteer for such courses. They did show, however, that greater computer experience, that is the length of time the teachers had been working with the computer, did not necessarily lead to more innovative usage. There was no difference between experienced and inexperienced teachers in their frequency of use of drill and practice, open-ended and data-handling software. However, those teachers with more than six months experience tended to use more problem-solving programs.

It is often the tool user who has most fun and who gains most value from the encounter with the machine and, unfortunately in many cases, that tool user is the teacher. Ogborn (1985) argues, therefore, that developments in CBL should emphasis the tool-like uses of the computer, but that the learner should take the active role of operator. In encouraging children to use the computer as a tool, we are mimicking out-of-school uses of the computer, with these children participating in activities relevant to such environments as the electronic office, and engaging in an exploration of knowledge in a way that is akin to the current research in Artificial Intelligence.

Many workers would argue that the computer can and should be used in more creative and liberating ways rather than as a drill and practice (beware the word 'teaching') machine (Chandler, 1983; Papert, 1981; Wilkinson and Patterson, 1983). Papert has argued eloquently against its use as a 'teaching' machine, suggesting that such a powerful technology can open up new fields of knowledge and encourage the development of higher level cognitive skills.

It is deeply worrying that Sheingold (1981) should find that drill-and-practice programs are offered to low achieving or disadvantaged children in the belief that they will benefit most from these "highly structured non-judgemental, infinitely patient environments," while their advantaged peers enter the expansive world of the computer as tool. This differential use is seen as encouraging a questionning autonomy in one group of learners, while their less favoured peers are caught in an environment which sets limits on independent thought, curtailing the exercise of options and the opportunity to reflect. It also provides one group with the skills and insights into the uses to which a computer may be put outside of the classroom, while the drill-and-practice class sees the computer as an electronic worksheet, a concept of little environmental value.

The debate on what we should do with computers in the classroom will probably rumble on for a good many years yet, and not all teachers will resolve the the question in the same way. O'Shea and Self (1983) emphasise the bewildering array of opinions as to the role of educational computers. At the same time they, like Chandler, are disturbed by the moves towards a more mechanistic education supported by much of the current computer software. For, as they say, it is not that it is wrong to practise sub-skills but if that is all there is to education, then it is severely impoverished.

One of the major issues in educational computing is in the definition of the goals of classroom computer use. These questions which are being asked about the educational benefits of chip technology have resulted in the computer becoming a focus and catalyst for change in education, because they mirror the diversity of views about the proper goals and functions of schooling. The concept of the computer as a tool opens up new directions in education, challenging the roles of both teacher and child and questioning our definition of 'worthwhile' knowledge and skills.

The production and dissemination of 'good' software will have little impact if teachers are not reassured about their own and students' changing roles (Johnson, Anderson, Hansen and Klassen, 1981), or, if they are not encouraged to to re-evaluate the structure of their classrooms (Amarel, 1984). They also need to be provided with the skills to select and use relevant software (Preece and Jones, 1985; Bleach, 1986; Jackson et al.,1986), and to evaluate the educational outcomes which result from a curriculum emphasising process rather than knowledge *per se* (Underwood, 1985).

Despite strong pro-computer attitudes, the criterion for the selection of all the teachers involved in the PLATO project (Amarel, 1984), the study found considerable disparity in the level of impact and change that teachers permitted to take place and Amarel emphasises the powerful effect teachers had on the process, and ultimately, the outcome of the implementation. This influence was shown in the disparity between mean pupil-time on-line, which varied from seven to seventy hours. In *laissez-faire* classrooms, computer 'jocks' commandeered the terminals, to the detriment of less forthcoming children who were frequently, but not always, female.

Amarel (1984) argues, however, that whatever the assumptions or attitudes of the educational fraternity are, concerning new social structures in the technological classroom, the probability of change is slim. Classrooms are intrinsically stable settings with well established cultures, social dynamics and work-related agendas, all rooted in the established curriculum. Arguing from Roger Barker's tenet that 'settings have plans for their inhabitants....' (1968), she suggests that this stable setting, which has resisted the influence of numerous innovations, is unlikely to be re-organised by even such a powerful tool as the computer. The demand characteristics of the classroom will continue to be paramount in the determination of people's behaviour.

1.6 Summary

There are a number of pressing issues to be resolved following the introduction of the computer into the classroom. Although hardware provision has been generous to the schools there are still important shortages particularly in the provision of peripheral hardware. One reason for this is the lack of government support for equipment such as printers for primary schools. A second reason, however, is the failure of teachers to perceive a need for such equipment either because they are still using 'small' programs which do not require additional hardware, or because they feel that a second processing unit is more important to allow all their children to have that vital hands-on experience.

A second issue arises out of the goals that should be set for computer use; the 'teacher' versus tool debate. This debate is intricately bound to teacher expectations and underlying philosophies of education. Changes in computer usage can be achieved, however, following in-service training. Training is itself the solution to the third issue, the lack of good software. It can no longer be said that all software is of dubious quality, the main problem now is making teachers aware of good material and how it can be used, and then persuading head-teachers to allocate resources to purchase a core of good material.

Issues of resource allocation and organisation are subsumed under the general instructional style the teacher elects to use. The use of open-ended packages demands immersion in the use of the machine and, of necessity, the computer must be available for blocks of time rather than on a simplistic rota basis.

1.7 Aims of the Thesis

The two main themes of this thesis stem directly from the issues discussed above. The discussion is directed towards the study of computers within the curriculum rather than as a focus of that curriculum. Within this context two of the important areas of concern are the influence of teachers as 'gatekeepers' to any educational innovation, and the importance of the computer in developing or stimulating concept formation and thinking skills. Sections Two and

Three report a series of investigations designed to shed light on these questions. However, the classroom is a complex environment which poses a number of methodological problems for any researcher. In Chapter 2, these research problems are discussed in some detail and this chapter provides the platform on which the later investigatory chapters are founded.

Thomas Kuhn (1970) asserted that paradigm shifts in scientific enquiry occurred, not through conversion, a change of heart or mind of the scientist, but through the replacement of an earlier generation by a new and yet uncommitted band of scientists. With this in mind, and noting the profound influence that the teacher has on the success and direction of any innovation, it was considered important to examine the attitudes of teachers-in-training to the use of computers in schools. Earlier studies, which are reviewed at some length, have largely considered the attitudes of practicing teachers or of their pupils. This new generation of teachers-in-training have grown up in the 'computer age' and may well have used one or more machines at home or in school, and it might be hypothesised that they will have a positive and more informed attitude to the use of the computer than teachers-in-practice. Section two (Chapter 3) of this thesis is, therefore, an investigation of the attitudes to classroom computer use of teachers-in-training and of practicing teachers over a three year period from 1983/4-1985/6.

The experimental work reported in Section Three (Chapters 4 to 8) is concerned with the role of the computer in encouraging the development of high level cognitive skills, specifically children's ability to bring order to the vast array of information impinging upon them. At the centre of this work is an investigation of children's classificatory ability, the importance of which is discussed in detail in Chapter 4. Chapter 5 investigates the types of organisational structures available to children and asks the question whether or not children have available the range of organisational structures that they are likely to meet when using computer data handling packages? The importance of computer-based data handling packages for the development of information handling skills , including classification and hypothesis formation, is reported in Chapters 6 and 7. The influence of teacher goals on the nature of educational outcomes is also highlighted here. The experimental evidence in Chapter 8 is directed towards the resolution of the teacher/tool issue in which comparisons are made between the effectiveness of different instructional styles of computer usage on the development of classificatory ability.

CHAPTER 2

ISSUES IN EDUCATIONAL RESEARCH

2.1 Introduction

Research in education is a contentious affair. Controversy surrounds both the methods and the goals of such research. It is a politically sensitive issue because it is linked, through demands to evaluate the educational process, to the assessment of both children and teachers. Secondly, educational research is a fertile ground for the continuation of the arguments between the humanists and empiricists in their approaches to the study of human behaviour. These issues are explored further in this chapter and the deliberations presented here provide the research paradigm used in the following investigative studies. The position taken in this thesis is that the evaluation of our efforts is both possible and necessary.

2.2 Current Pressures to Evaluate Education

Research in education is essentially directed towards evaluating the effectiveness of the educational process. This 'catch-all' generalisation hides a multitude of issues concerning the goals of education which are beyond the scope of this study. As demands for accountability increase then, necessarily, evaluation studies become more important and more complex. Educational evaluation is now big business; a major industry with its own terminology, training programmes and publications (Venezky, 1983).

There are many reasons for the growing interest in the formal evaluation of education. Snow and Yalow (1982) point out that increasing demands for accountability in American education in the 1970s were due both to economic pressures and to the view of education as a tool for social justice. Out of such social pressures came projects such as HEAD START and

SESAME STREET, but it is the economic pressures which dominate in the 1980s. Now American teachers have to prove their effectiveness in the classroom to the satisfaction of parents, who may resort to the courts if they feel teachers have failed their children (e.g., Dedra P. v. Turlington; cited in Snow and Yalow, 1983). As a result, teachers are increasingly required to specify educational objectives which have overt behavioural outcomes and, in at least 30 States, 'minimum competency testing' occurs in all state-run schools (Shoemaker, 1980). Such pressures are equally alive in Britain today. A major factor in the recent industrial action in our schools (1984-86) was the demand of government for teacher assessment, and news headlines such as: "Annual test could force pupils to repeat a year." (The Independent, January 31, 1987, p. 2), suggest that 'minimum competency testing' may be introduced into British education alongside a 'core curriculum' in future years.

2.3 Approaches to Educational Evaluation

Evaluation may take a number of different forms depending on the reasons for that evaluation and the methodology of data collection. The nature of any evaluation is generally defined by a series of dichotomies: is the evaluation formative or summative; will it take the form of a controlled experiment or will it be a collection of observations over time? As Kemmis (1978) has pointed out, these different approaches to evaluation have arisen from the different views of the nature of generalisation, of the nature of explanation, and of the nature of social science itself.

The simplest summative evaluation looks at student outcomes using the pre- and post-test design. Venezky (1983) suggests that an equally valuable approach is the time-series design. Here student outcomes after the introduction of the experimental treatment are compared to outcomes in the same context prior to the onset of the treatment, as in Osin's (1980) evaluation of a CAI mathematics curriculum, and not to the performances of a control group. Venezky argues that although the time-series design lacks the experimental rigour of the control group design, it does have greater ecological validity. Both, however, are rooted in the nomothetic tradition of the scientific method.

It is often the case that the researcher will want to go beyond the measurement of achievement performances through the use of teacher and pupil questionnaires and classroom observations. Venezky calls this the fieldwork additive model of evaluation, and he suggests that such observational material adds significantly to the interpretation of achievement measures. This additive model is the meeting ground between the nomothetic and hermeneutic approaches to evaluation. In the latter case the evaluation is often termed 'illuminative', emphasising the importance of understanding the educational milieu. The methodology of such evaluation is observational case studies and its strength is its high level of ecological validity, but it lacks the rigour of the nomothetic approach.

2.4 Empiricism: a Controversial Approach in Educational Research?

To set out to conduct relevant and valid research in the classroom is a daunting task. Compared to the laboratory, the classroom is a highly complex environment, a seething mass of interdependent variables which, in many eyes, are uncontrollable in any formal empirical sense. It is this very complexity that has led to one of the deep schisms in perspectives of studies in the classroom, that is the rift between the empiricists on the one hand, generally operating from a base of logical-positivism, and the more hermeneutic research traditions on the other hand. Within Europe as a whole there has always been a strong hermeneutic tradition, in part due to the strengths of the philosophical and sociological traditions of academic Europe. On the other hand, in America, and to a lesser extent in Britain, psychologists have tended to follow the empirical tradition to educational research.

Today the tide has turned strongly in the favour of non-empirical research (Kemmis, 1978). It has been argued that the aim of empirical research is to explain, while that of the hermeneutic school is to understand the phenomena under investigation (see von Wright, 1971). This is exemplified by Piaget and Inhelder's (1947) argument that the results of the types of pre- and post-tests frequently used in empirical assessments of learning, can only give an indication of the efficiency of mental activity while failing to illuminate our understanding of the mental operations themselves. Kemmis (1978) graphically sums up the doubts many psychologists and educationalists have about the use of the empirical paradigm in the classroom, in the following questions:

> "will our analytical dismantling of the phenomena of education enable us to put together a better, more coherent package, a more worthwhile educational experience, or build a better society? Or does the analysis do violence to our notion of education? Like others concerned with the process of education, the evaluator must choose his methods carefully if he is to to avoid a charge of vivisection." (p. 45)

Is empiricism to be abandoned? Kidd and Holmes (1984) have argued that empirical procedures are ineffective because they merely evaluate a treatment under a specific set of conditions, and this is a fundamental weakness of the approach. It can be argued, however, that this is the very strength of empiricism: the conditions of testing are well-defined and do not, or at least should not, vary along unknown dimensions. Teachers can benefit from research information which will tell them under what conditions a piece of curriculum is known to work, but this is not to say that these are the only conditions for success. The less competent teacher may stay within the guidelines provide by the research findings, while the more innovative teacher can build on a firm base of knowledge (Underwood and Underwood, 1987).

A view sometimes voiced in defence of empiricism is that critics are unhappy with experiments because they, the critics, are unable to conduct experiments properly. There certainly exist plenty of examples of poorly controlled experiments which give rise to uncertain conclusions, and their authors are among the strongest critics of the scientific method, but we cannot reject a methodology on the basis that someone, somewhere is unable to use it cleanly. In assessing the value of this research method we should, surely, look at good experiments. A poor experiment is arguably less use than no experiment at all, but are there any good experiments in the educational domain? Clark (1983, 1984) suggests that, for the area of research on the new technologies and education at least, the answer is no!

Clark's reservations about the value to education of new technologies, including that of educational computers, have already been noted in the opening chapter of this thesis. He has argued that although the computer may have a brief novelty effect on improving learning, the change is transitory. In general, the traditional well-prepared teacher can do just as well. Reservations is too restrained a term, however, when we consider Clark's views on the research which has been undertaken to justify the increased use of new technologies in the classroom. In the two papers cited here he has led a thoughtful, articulate and scathing attack on research purporting to show learning benefits from the use of various technologies in the classroom. He argues that careful re-analysis of published research data reveals consistent evidence of the failure of any of the new technologies to significantly increase learning. Further, where data do indicate performance or time-saving gains for one medium over another, the data could be equally well explained by other hypotheses, so ill-controlled are the experiments. In this indictment of current educational research Clark is presenting the antithesis of Marshall McLuhan's (1964) view that the 'Medium is the Message' when he says:

> The best current evidence is that media are mere vehicles that deliver instruction but do not influence student achievement any more than the truck that delivers our groceries causes changes in our nutrition. (1983, p. 445).

This is *a priori* a false argument. All year access to summer fruits and vegetables has changed our eating habits. Fast road or rail links do effect the desirability of property. The speculative building of the Metropolitan rail line south from London is a clear case in point. There is a wealth of literature in the social and economic sciences which refutes Clark's argument.

Clark suggests that there are many reasons for the failure of past research to produce valid results but that the two most important problems result from the confounding of variables in the experimental design and the failure to account for novelty effects in achievement gains. For example, Kulik, Kulik and Cohen's (1980) re-analysis of published data showed that differential achievement gains by computer-users, compared to that of non-computer-users, disappeared when the teacher variable was removed. It seems that differences in the attitudes and aptitudes of teachers can have effects as great as those produced by CBL. A second interpretation of these findings might be that the use of CBL can mask the inadequacies of teachers, inadequacies which are apparent under non-CBL conditions. Clark also cites work which shows that performance gains from computer usage drops off dramatically after the fourth week of use (Kulik, Bangert and Williams, 1983) but argues that few studies are conducted over even this brief time-scale..

Is Clark's message one of despair, or of admonishments tinged with guarded hope? Is he suggesting that no comparative studies of learning under different teaching strategies can be valid, or are researchers simply being urged to tighten up their experimental procedures? In this thesis the more optimistic view of Clark's work has been assumed, but his pertinent criticisms have been used in developing the experimental procedures used here.

2.5 The Computer and Educational Evaluation

The resurgence in the demands for accountability and the widespread movement of computers into the classroom are contemporaneous events. Are these two very significant changes in the educational system unrelated events or has one proved to be the spur to the other? For example, Dede (1981) has argued that one important outcome of using the new technologies in schools is that genuine economic gains can be made, without a cut in the quality of education. This, however, is dependent upon a large enough clientele being persuaded to use the machine, to cover the high software production costs, for software is incredibly cheap to use and reuse. The 'economies of scale' which can result from educational computer use are already proving attractive within higher education in Britain and across the educational perspective in North America. If such economies are to be achieved, and materials are to be used nation wide, then there will need to be stringent quality control of instructional packages. No economies will be achieved if the software has to be revamped once in extensive use, and so it must be right before it enters the public domain. Here, Dede is suggesting that the use of new technologies is a major stimulus to educational evaluation as they require clearly specified national curriculum goals at the outset.

This is not the only way in which the classroom computer can influence the evaluation of education. Venezky (1983) argues that ICAI (Intelligent Computer Assisted Learning) will remove the distinction between formative and summative evaluation. Programs such as ADS (Marshall,1980) and BUGGY (Brown and Burton, 1978) are capable of building a model of a student's knowledge structure within a given domain. This understanding of the student is then used to design an individual learning programme for that student, which can be adapted as the student's responses reveal more and more about his level of understanding.

Both the move to 'economies of scale' and the development of ICAI will have profound effects on education and on its evaluation. Specifically, both modes of computer-use demand clearly defined and clearly testable educational objectives, a need in sympathy with the modern moves towards accountability in education discussed earlier. However, the use of the computer in the classroom may also subvert that accountability and provide major problems for the evaluators. Dede (1981) has argued that the use of classroom computers will alter our concept of 'intelligence.' In the next few decades, the ability to memorise large numbers of facts will be regarded as a trivial ability as we come to rely on artificial memory stores. The intellectual skills of analysis, synthesis and evaluation will now be seen as paramount. The difficulties of assessing the development of such skills has already been discussed in Chapter

1. The problem here is that the demands of accountability are not easily met in such a curriculum. Factual recall is far easier to test than the development of skills, particularly cognitive skills.

2.6 Research in the Cognitive Classroom

The studies reported here are concerned with the value of classroom computers as an aid to the development of children's thinking, and the main educational goals under consideration lie in the cognitive domain. This perspective of education is expressed by Bruner (1971) in his view of the five major aims for schools, which are paraphrased below:

1. School should encourage children to discover the value and amendability of their own guesses, to discover the utility of first order approximations in approaching a problem and realise the importance of hypothesis testing.

2. School should help children develop confidence in their ability to solve problems.

3. School should foster self-propulsion in children.

4. School should help children to develop economy in the use of mind and encourage children to look for relevance and structure.

5. School should help children to develop intellectual honesty.

In this perspective of education, the development of children's thinking is paramount. The question here is how do we measure whether or not strategy 'A' or 'B' has brought about desired changes or indeed had any impact at all? In common with many areas of research, including the natural sciences, it is often easier to measure the product of thinking and learning as opposed to the process that enabled that development. As has already been discussed in 2.3 and 2.4, there are well established research techniques for assessing children's output but far fewer for assessing the changing mental structures themselves. No one would deny that it would extremely useful to be able to watch a child's mental operations at work, tapping into the mind as a computer programmer might into the computer while debugging a program, but it is extremely difficult to imagine how this will be possible. It is no surprise, therefore, that much educational research concentrates on learning-outcomes. The study of learning outcomes is valuable, for, just as the study of a coastal cliffline can provide inferential evidence of marine processes at work, so the product of the learning process can give insights into children's thinking. The core work of this thesis is, therefore, concerned with evaluating the impact of classroom computer use on children's cognitive development through the assessment of learning-outcomes.

To some, this essentially cognitive view of education would appear to be one-sided. There appears to be no consideration of children's social or physical development, nor of those environmental factors impinging on a classroom, which render it unique within the set and at the same time make it recognisable as a member of the category of 'classrooms.' This is too harsh a judgement, however. To place cognition at the heart of formal education is to emphasise the unique role of the teacher. When considering, for example, the social development of the child, it can be argued that parents should be the prime influence on the child followed by a number of significant others including teachers and other children. Socialisation is a process which cuts across the home/school boundary, but the development of formal modes of thought lies within the classroom domain alone (Hughes, 1986). Nevertheless research into formal education cannot ignore those factors which act as inhibitors or facilitators of the learning process. Two such factors are considered here. The nature and degree of prior learning of the child, the context in which future development takes place, and the attitude of teachers, for they are the 'gate-keepers' of any classroom innovation. If teachers believe in the education they are offering then progress will be made, if not then the educational experience is less likely to be successful.

2.7 Summary

For Kemmis (1978), it is futile to argue that there is one right approach to educational evaluation, rather we should be considering how we should evaluate student learning in different curricula contexts. This is the approach that has been taken in the work reported here. The central question considered is whether or not the use of classroom computers and relevant software can stimulate the development of underpinning cognitive skills. Three empirical studies, involving pre- and post-testing of matched subjects, were conducted (Chapters 7 and 9) to evaluate the effectiveness of the computer as a stimulus to categorisation skills. In all work careful note was taken of Clark's criticisms.

The empirical work in Chapter 7, which considered the use of information-handling packages in the classroom, was further developed through a hermeneutical study of eighteen classrooms (Chapter 8). This study of children using information-handling packages was undertaken in order to come to a greater understanding of the cognitive processes operating when children use the computer in open-ended activities.

The first pieces of research to be described investigated important factors in the educational process, the attitude of teachers (Chapters 3 and 4) through the use of a questionnaire, and the level of prior knowledge about modes of structuring information which children bring to the information-processing classroom (Chapter 6).

It is suggested that this field-additive approach to research allows us to use each of the research methods to compensate for the weakness of the others, and in so doing, to provide a more complete view of the impact of CBL than if one method had been used to the exclusion of others.

SECTION TWO: ATTITUDES

CHAPTER THREE: ATTITUDES TO THE COMPUTER - A REVIEW

CHAPTER FOUR: ATTITUDES OF PROSPECTIVE AND SERVING TEACHERS TO EDUCATIONAL COMPUTER USE- AN INVESTIGATION

CHAPTER 3
ATTITUDES TO THE COMPUTER

3.1 Introduction

A number of recent studies have investigated our attitudes towards the use of computers. Some observers view such research as irrelevant (see Menzies, 1982; Simon, 1977). They argue that the attitudes of individuals and groups are generational idiosyncrasies, being captured at a time when computers are being introduced into the home, the school and the workplace. As such groups retire, a new computer-literate generation will take over and use computers as matter-of-factly as our generation uses the telephone. On the other hand, Caporael and Thorngate (1984) suggest that there is no evidence to support the view that the next generation will be any more positive towards the computer than our present generation, and that research into current attitudes towards the computer may serve to illuminate problems and issues arising out of the spread of this new technology. The present study was undertaken to identify those problems and issues which might arise from teachers' perceptions of the usefulness of the computer in their domain.

Investigations to date can be differentiated by the general aim of the investigation, the nature of the sample population, and the research method employed. Much of the work has been directed towards assessing the depth of knowledge and beliefs held about the role of the computer in society, either for the general population (Ahl, 1976), or for sub-groups, such as the teachers and educational administrators in Lichtman's survey (1979), or the children in the studies by Moore (1984) and Turkle (1984). In general the research method employed has been survey by questionnaire, although Turkle used observational studies and non-structured interviews.

3.2 Adult Attitudes to the Computer

Ahl's study sampled 843 'members of the public' [1] in the USA and Western Germany, of which 543 were under 20 years of age. The results from his 17 item questionnaire are summarised in Table 3.1. Although both his young and older subjects were generally positive in their reponses, viewing the computer as adding to the quality of life of a society, there were concerns over the de-humanising potential of the computer and about the effects of computerisation on future employment, particularly among the younger group (items 7 and 13 : 39.9% and 40% respectively -- low scores relate to negative attitudes).

Lichtman extended Ahl's questionnaire, adding six questions relating to the educational use of computers, to tap the feelings of his 162 initial and in-service teachers[2] and 27 educational administrators (Table 3.1). The members of this sample were all participants at a summer school, which suggests that they would be from the more innovative and flexible end of the teacher spectrum. Several interesting points arise out of Lichtman's work. Although one might have predicted the fact that the teachers revealed less positive attitudes to the computer than Ahl's sample, which almost certainly incorporated a number of computer buffs, the discrepancy in attitudes between teachers and educational administrators is less predictable but still illuminating. The latter group were more enthusiastic about the computer in general and its role in education in particular, than were the teachers, even though they perceived the computer as offering a greater threat to their jobs (item 23; teachers, 16%; administrators, 22%). They also showed less fear of a degraded and isolated human society following the spread of computers through society (items 7 and 8; 26% and 15%) compared to the teachers (55% and 30%). From this study it would appear that teachers, at least, are sceptical about the benefits of computer use, although they too acknowledge the pervasive influence of the machine on society (item 5).

[1] No definition of this population is offered and it seems that it was composed of readers of Creative Computing Magazine. All data should therefore be viewed with care and an assumption must be that the sample is both knowledgeable and generally positive towards the computer.

[2] Initial teachers are teachers in training. In-service teachers are trained teachers.

Table 3.1

Summary of results of the surveys of computer attitudes by Ahl(1976) and Lichtman(1979). (after Moore, 1984).

Test Item	Public: Adult 300 a	Public: Adult 300 b	Public: Youth 543 a	Public: Youth 543 b	Educators: Teachers 162 a	Educators: Teachers 162 b	Educators: Administ. 27 a	Educators: Administ. 27 b
1. Computers will improve education	86.6	5.9	84.2	4.5	64.0	9.0	96.0	0.0
2. Computers will improve law enforcement	81.9	3.3	70.0	10.1	60.0	10.0	89.0	7.0
3. Computers will improve health care	78.6	5.3	54.1	11.9	51.0	14.0	67.0	4.0
4. Credit rating data banks are a worthwhile use of computers	64.2	13.4	64.0	7.6	83.0	4.0	85.0	4.0
5. A person today cannot escape the influence of computers	91.6	4.0	66.6	17.7	80.0	6.0	92.0	0.0
6. Computer polls and predictions influence the outcomes of elections	48.1	27.5	44.2	26.9	48.0	24.0	52.0	18.0
7. Computers de-humanise society by treating everyone as a number	37.4	50.3	39.9	30.6	55.0	22.0	26.0	48.0
8. Computers isolate people by preventing normal social interactions	18.7	62.5	20.9	42.5	30.0	33.0	15.0	74.0
9. Computers are best suited to repetitive monotonous tasks	80.0	10.3	57.0	21.6	54.0	17.0	41.0	30.0
10. Computers are a tool just like a hammer or lathe	72.6	14.7	61.3	23.4	77.0	8.0	81.0	5.0
11. Computers slow down and complicate simple business operations	17.6	66.4	17.4	68.8	12.0	69.0	11.0	81.0
12. Computers will replace low-skill jobs and create jobs needing specialist training	71.0	15.0	61.8	14.4	36.0	22.0	52.0	15.0
13. Computers will create as many jobs as they eliminate	62.5	16.4	40.0	29.1	35.0	30.0	44.0	26.0
14. Computers are beyond the understanding of the typical person	25.2	61.6	30.6	49.2	30.0	47.0	33.0	52.0
15. Computers make mistakes at least 10% of the time	9.6	76.7	10.3	60.0	30.0	38.0	7.0	70.0
16. Programmers and operators make mistakes but computers are error free	67.0	19.3	72.3	13.3	55.0	25.0	70.0	15.0
17. It is possible to design computer systems which protect the privacy of data	60.2	26.4	48.6	15.9	46.0	18.0	70.0	18.0
[Lichtman's additions to Ahl's questionnaire]								
18. Our country would be better off if there were no computers					5.0	78.0	0.0	100.0
19. If there was a computer in my classroom it would help me be a better teacher					36.0	22.0	48.0	15.0
20. Some day I will have a computer or a terminal in my own home					20.0	43.0	33.0	26.0
21. Computers can teach mathematics					58.0	16.0	52.0	15.0
22. Computers can teach reading					47.0	20.0	52.0	15.0
23. A computer may someday take my job					16.0	67.0	22.0	59.0

a = SA/A ------ Strongly Agree/Agree ---- Collapsed data
b = SD/D ------ Strongly Disagree/Disagree --
All figures are percentages of people agreeing with the question.

This resistance to computer technology also appeared in the study by Johnson, Anderson, Hansen and Klassen (1981) of teacher attitudes as part of the Minnesota project, a large-scale investigation of computer use and literacy with particular reference to science education. In this study it was clear that teachers were fearful of the machine taking over their jobs. O'Shea and Self (1983) argue that this is an understandable fear as most programs do aim to mimic human teaching activities, although this concern was less apparent in Lichtman's (1979) findings. Teachers were also unsure of their role in a computer-rich environment and felt that they neither had the time nor the incentive to come to grips with the technology and the potentially new pedagogical techniques required for its successful incorporation in their classrooms. The high monetary value of the resource also added additional strains and responsibilities on the teachers which they were unwilling to countenance. This study conducted at roughly the same time as Lichtman's work, again emphasises the more cautious approach to computers expressed by teachers, both within education and within society in general, compared to other participants in the educational field.

A later study by Opacic and Roberts (1985) has shown that the attitudes of teachers are complex and governed by a number of factors. They questioned a sample, based on sex and subject area, of seventy-nine secondary school teachers from six schools. Their study investigated both the use and potential use of CBL techniques. The main findings were that more positive responses to the use of computers were received from male teachers and from science teachers. Overall, approximately 60% of the sample expressed positive attitudes. Those teachers who were not using, or contemplating using, the computer argued that this was because they had received insufficient information and/or training to enable them to conduct worthwhile activities with the computer in the classroom.

The pervasive nature of computers is delightfully highlighted in Turkle's (1984) anecdotal research in which she discusses computer metaphors. Turkle argues that while we think of computers in human terms we are also beginning to think of ourselves in computer terms. Humans are defined as highly skilled information systems while problem solving is discussed as debugging thought. The author's own experience confirms the strength of the computer metaphor, when even such classic educational/ psychological issues as the 'Nature versus Nurture' debate are rewritten by first year Psychology students as the 'Pre-programmed versus Empirical Search' debate.

Turkle (1984) also cites a number of cases highlighting the confusion, concern and often inadequacy that some adults feel as they enter the computer-age. Parents are worried about the addictive nature of video games, comparing the addiction to mindless television watching: a false assumption in Turkle's view. She states that those who appear afraid of the computer use the most mechanistic metaphors to describe the computer. This appears to be confirmed by the results from Ahl (1976) and Lichtman (1979); the least positive group, teachers, also expressed the greatest concerns about the de-humanisation of society. As Turkle suggests, the image of the child with a machine is not compatible with a Rousseau-like innocence and the flowering of the young child's mind, an important underpinning philosophy for the child-centred educational movement.

Swinton, Amarel and Morgan (1978) have shown that, even when teachers' attitudes are deemed to be positive to the computer, the educational outcomes of placing computers into the classroom will be highly individual. Their role was to evaluate the National Science Foundation of America's project Programmed Logic for Automatic Teaching Operation, PLATO for short. The PLATO project involved children of lower and upper primary school age (Grades 1 and 2 and Grades 4 and 6), and all the teachers were volunteers with a keen interest in the use of the computer in the classroom.

In their evaluation they highlighted both the differences in teachers' responses to the computer in their classrooms, the dramatic and powerful effects teachers had on the process and, ultimately, the outcome of the implementation. On the crude measure of pupil time on-line, this might vary from an average of seven to seventy hours. In *laissez-faire* classrooms computer 'jocks' commandeered the terminals, often to the detriment of the less forthcoming child who was frequently, but not always, female. Classes involved in developing reading skills through the use of PLATO spent on average only 10% of the time on-line compared to those pupils working on some aspect of mathematics. This raises the question as to where the computer will be most usefully employed? The teachers in the PLATO project made their views apparent by their actions in the classroom although the results could be accounted for by age-range. The reading schemes were used with the younger children (Grades 1 and 2), while the older group completed projects in mathematics.

Two other interesting findings of this evaluation were the ease with which the teachers coped both with non-formal interaction with the computer and with the growing technical expertise of their young charges. They found that there was considerable disparity in teachers' opinions of permissable student interaction with the computer. Most of the teachers were unhappy when computer contact took place outside of the formal setting of the organised lesson, but a small band of teachers saw such contact as providing new and welcome educational opportunities. For example one teacher removed several pupils from the machine on the grounds that they had completed their task and it was no job of theirs to tutor other students, that is he or she was unhappy about pupils stepping outside of their role as learner and infringing on the role of teacher. A second teacher actively set-up self-help groups, each with its own child leader to co-ordinate the work.

The reaction of teachers to pupils' growing expertise was also illuminating. One teacher closed down the system because pupils were hacking into the programs rather than 'doing maths.' The contrast came from a teacher who encouraged pupils to gain computer know-how by watching and experimenting, in order that the pupils should gain increasing levels of independence. This fear of pupil expertise threatening the teacher's role as a 'repository of all worthwhile' knowledge is very real. We all have our own anecdotes including that of the primary school teacher who continued to let her colleagues laboriously load programs into the machine when an effective booting mechanism had been provided. If it is difficult to share our expertise with colleagues, how much more frightening must it be to share expertise with our pupils?

The work of Swinton et al. should encourage a cautious interpretation of past and future research in this area.

3.3 Student Attitudes to the Computer

The attitudes of children and students towards the computer has proved a fertile research ground in recent years, but do children feel similar alienation to Turkle's (1984) adults? Ahl's (1976) study, in which two-thirds of the sample were under twenty years of age, suggests not.

Klassen, Anderson, Hansen and Johnson (1980) conducted a major investigation of computer use and literacy with particular reference to science education. A test of computer literacy was administered to 929 junior and senior high school students before and after receiving a term of computer related courses. The level of literacy of a control group of 177 students, who did not receive any computer education, was also investigated. The questionnaire assessed knowledge of computers, including knowledge of hardware and programming, data-processing, applications, and social impact, and a sixth dimension of computer literacy defined by attitudes and values.

The study shows an initial positive attitude towards the computer for all groups (Table 3.2). Pupils enjoyed using the computer, were not anxious and felt they could use the machine effectively, were keen to see the computer in school and valued its technological role and place in society. These initial scores became even more favourable in the post response situation, irrespective of whether students had been enrolled on a 'computer course' or not, and irrespective of the nature of that course, that is whether it involved programming, computer awareness or appreciation or the use of the computer as a learning tool.

Table 3.2

Summary of Results for the Minnesota Educational Consortium Questionnaire on Computer Literacy (after Klassen et al.).

Test Dimension	Score Range min.	max.	Computer users (N=929) pre mean	s.d.	post mean	s.d.	Non-computer users (N=177) pre mean	s.d.	post mean	s.d.
Composite Knowledge Score	0	49	24.9	8.9	28.9	8.9	21.6	7.5	22.9	8.1
Attitudes										
Enjoyment	5	25	18.6	3.6	19.0	4.1	16.7	3.5	17.5	3.7
Anxiety 1	5	25	11.1	3.3	10.5	3.5	11.8	3.1	11.5	3.3
Efficacy 2	5	25	16.5	3.0	17.2	3.4	15.8	2.9	16.4	3.1
Educational Support	5	25	18.4	2.7	18.9	3.0	18.1	2.7	18.5	2.9
Social Value	5	15	13.8	1.4	13.9	1.4	13.5	1.5	13.6	1.6
Technological Value	4	12	11.3	1.8	11.5	1.9	10.8	1.8	11.1	1.9

1 Negative construct, low score indicates less anxiety.
2 Efficacy - self-confidence in computer use.

The failure to match the experience and attitudes of the control group to that of the experimental group, prior to the provision of computing experience to the experimental group, is to be regretted. On all measures of experience and attitudes the control group recorded less favourable scores than the experimental group, and this hampers any evaluation of the impact of the computing courses on improving knowledge and attitudes.

The work of Matthews and Wolf (1979) and Wilson and Trenary (1981) both found that undergraduates on computer courses have more positive attitudes to the computer than students on, respectively, general technological courses and business administration courses. This appears to be a self-fullfilling prophecy. More interesting is the fact that the business studies students, in the study by Wilson and Trenary, were more realistic about the computer's capabilities than the largely science and technologically orientated students on an elementary computer science course, and that experience of the computer through programming courses, did not produce an equivalent positive attitude to the computer among business studies students as it did among the more technologically orientated students. For many of us this result may not be surprising, business studies students need to be users not developers of programs; programming might well have appeared irrelevant to them and it might be conjectured that an inappropriate knowledge can be destructive rather than constructive in the development of attitudes.

A number of attitudinal dimensions have been identified in the research studies discussed so far. In the case of Wilson and Trenary (1981) the differences in attitudes are measured on three constructs; Acceptance, Trust and Error-proneness of the computer, all of which have equivalents in Ahl's (1976) and in Lichtman's (1979) work. While Matthews and Wolf (1979) suggest that there is computer-attitude continuum from positive to negative attitudes.

Matthews and Wolf identified their attitudinal continuum by factor analysis. They argue that two clear factors emerged from an oblique factor solution; factor one being defined by twenty-five content-negative items, three positive items and five non-interpretable loadings, while factor two includes fifteen positive items and one negative plus one non-interpretable item. Moore (1984), however, argues that although the two factors are distinct they account for less than one-third of the variance, and that the inter-factor correlation of -0.36 represents an inter-factor angle of 110 degrees suggesting an orthogonal or non-correlated solution incompatible with the continuum interpretation. This suggests that the pattern of attitudes is more complex than the simple continuum suggested by Matthews and Wolf; much of the attitude space has not been accounted for and a multi-dimensional solution would be more appropriate.

Moore (1985) designed a computers and robots attitude questionnaire (CARAQ) to assess attitudes of secondary[1] school pupils to computers pre and post a wide range of computer education courses. The general aim of the study was to help teachers and curriculum developers evaluate the effective outcomes of their courses. The CARAQ consisted of seven scales assessing attitudes to the use or role of computers in: schools, leisure, careers, employment and the future, plus the impact of computers on society and the potential threat associated with wider computer use.

A sample of 1,274 third year pupils (mean age = 14.4, 628 = males, 646 = females) formed the initial response pool, of which 911 (433 = males, 478 = females) answered the CARAQ for a second time one year later. Controlling variables in Moore's study included sex; ability, as defined by Piagetian stage of mental development; course of study which include a computer studies group, a science and technology group and a low science group; and exposure

[1] 11 to 18 years

to computer assisted learning. The initial responses to the questionnaire show significant sex differences; girls were less positive to the computer on all seven scales. This concurs with Newbold's (1982) study in which the male:female ratio of entrants to computer studies examinations is roughly 3:1. This sex bias is confounded by a 3:1 male:female ratio in Moore's computer studies group and a 1:3 ratio in the low science group, who were also less positive to the computer on all CARAQ scales compared to the other two subject groups.

These attitudinal differences were confirmed by McKelvey's (1983) observational study of six Canadian schools and by Hughes, MacLeod, Potts and Rodgers (1985) working in Scottish schools. In a survey of 102 children, divided equally into two groups of seven and ten year olds, who were pupils at either a predominantly middle class or a working class school in Edinburgh. They found that the view that computers are for boys was pervasive across much of the sample, and that girls were as likely to express this opinion as boys. The finding was particularly strong for working class children. This was despite an overall positive attitude to computers and an enthusiasm to use the machine at home and school expressed by most of the children, irrespective of age, sex, or class. Such sex differences are particularly worrying when we consider Chapman's (1985) view of the computer as the key controller of information and therefore skills in computer use as an access to power in the modern world.

Again the more positive response by students undertaking computer studies courses is self-explanatory; as is the decline in positive attitudes from third to fourth year. The latter can be seen in a general decline in positive regard of school over time (Mackay, 1971; Choppin, 1974). What is of greater interest is the decline in positive attitudes towards the computer over the year of the study for the pupils involved in computer studies. This decline is less apparent for pupils who are involved in out-of-class activities with the computer, however. It was hypothesised that the failure of programming experience to encourage more positive attitudes in business studies students (Wilson and Trenary, 1981) was a result of a mismatch of needs. Programming was simple an inappropriate skill for these students to learn.Would these computer-experienced students have been more positive in their perceptions of the computer if their experience had been directed towards relevent management skills, such as those of information retrieval or word processing, rather than towards programming? This same hypothesis could explain Moores's (1985) results. Indeed, the relevance of computer studies in schools is being questionned (DES, 1984; The Secretary of State for Education, 1984). It can be argued that it is far more important, for most of the population, to learn to use the computer as a tool in our chosen subjects, rather than learning about the computer *per se*. Equally it may be that computer studies is a poorly taught subject in the research cases investigated, possibly because of ill-equipped teachers. This may not be too surprising when we consider the limited training many teachers have been able to acquire in the field.

The general significance of these findings is, however, that contact with the computer does not always lead to improved perceptions of its role. Indeed, Frates and Moldrup (1980), working with first year undergraduates, showed that although less than 15% had knowledge of computer processes or had written a program, over 90% felt that the computer had a significant impact on their lives and had strong attitudes towards the computer. Thomas's (1976) sampling of 1,100 seventeen to nineteen year olds, highlights the difference between general knowledge of computers and specific information; for example many pupils in his computer literacy study were fully aware of the likely impacts of computers on the job market, as defined by the questionnaire, but they showed a very poor specific knowledge. They were unable to define the term hardware and were unaware of the mechanisms of computer fraud, and this included pupils responding after a term of computer studies. This suggests that attitudes to computers are based upon ephemeral world knowledge rather than formal and specific instruction.

Confusingly, contradictory evidence comes from the work of Anderson, Klassen, Hansen and Johnson (1980-81), the second half of the Minnesota project, defined as computer-based learning experiment. This study involved 340 pupils, aged between fifteen and seventeen with equal male:female ratios within both age groups and within experienced and non-experienced computer user groups. The experimental group, consisting of 216 pupils, was exposed to a short interactive science lesson on the computer (average length 20 minutes). Although the experimental group showed no difference in computer awareness (general knowledge of the computer) compared to the control group (Table 3.3), in either the pre or post experience questionnaires, they did show positive improvements on three dimensions of attitude; enjoyment, anxiety and self-efficacy (self-perceived ability to deal with computers). After six months the improvements on enjoyment and self-efficacy had disappeared when compared to the responses of the control group, but the experimental group continued to be significantly less anxious about the use of computers.

Table 3.3

Levels of Computer Awareness for the Computer User and Control Groups at the Three Stages of Monitoring (after Anderson <u>et al.</u>).

	Level of Computer Awareness			
	Pre Test	Post Test	After six Months	S.D
Computer Users (N=216)	5.6	5.6	6.4	2.3
Control (N=153)	5.6	5.6	6.0	2.1

Two other findings of the study are of interest. The six-month follow-up study showed an increased awareness of the computer for both the experimental and control groups but that that increase was significantly greater for the computer users from the original experiment (Table 3.3). Anderson <u>et al.</u> (1980-81) suggest that the computer user group were seeking out new opportunities to interact with, and to find out about, computers, that is these students were in some way more receptive to information about computers.

The second point arising out of this study is a result of one of the three conditions of use applied to the computer user group. One third of the sample were exposed to a simulated malfunction of the computer while completing their lesson. Although this malfunction caused no loss of work and was speedily corrected by the teacher, pupils in this condition were less confident about their ability to use the computer (self-efficacy) than the other computer users, a loss of confidence which persisted after six months, although they were still more positive than non-users. These pupils were also more likely to anticipate computer failure in other situations. This finding is particularly important in assessing the likely response to computers by teachers and pupils in the U.K. The hardware being rapidly introduced into school in the early eighties was prone to malfunction. In particular tape loading with the early BBC Model A machine was a hit and miss affair. For many teachers and pupils this was their first experience with a computer and, although the findings of Anderson et al. are on the whole encouraging, they do suggest that the haste to computerise education might have prolonged effects including a low self-perception as a computer user for those teachers and pupils who experienced repeated hardware failure.

3.4 Summary

The collective evidence so far suggests that the population, in general, is well aware of the increasing impact that the computer will make on their lives. For many groups there is excitement and acceptance of the benefits that the computer will bring, but some groups are more cautious in their acceptance. Teachers, in particular, are concerned about the negative impacts of the computer and doubt the overall usefulness of the machine at least in their own area of expertise. Attitudes to the computer appear to be formed from world knowledge rather than more formal contact with the machine, although the data are contradictory on this point. Poor experiences with a computer can leave a lasting mark, however, reducing the users confidence in their own ability to handle the machine and producing higher expectations of machine-failure.

There are disturbing indications of sex differences in attitudes to the machine and it is to be regretted that in the excellent study of pupil attitudes by Anderson et al. (1980-81) there was no comment on this aspect of their data, although the data were collected. It could be hypothesised, however, that the less positive response of Lichtman's (1979) teachers compared to the subjects in the studies by Ahl (1976), Matthews and Wolf (1979) and Wilson and Trenary (1981), was due to an unequal distribution of the sexes in the samples. Although no sex-type data were presented in these studies the teaching profession has a strong tradition of female employment whereas one might conjecture that the subscribers to computer magazines or students on science and technology courses would be predominantly male, and this may account for the differences in attitudes found. The study by Johnson et al. (1981) questions the logic of this argument, although they again fail to comment on this aspect of their data. They specifically questionned science teachers, predictably a group which one might expect to have a greater number of males than females, nevertheless this group also expressed grave reservations about the computer in education.

On the whole, the research reported here suggests that teachers, in their role of 'gate-keepers' to educational innovation, may act as a barrier to computer use in schools. However, the impact of the computer on Western society has been not only profound but also swift, and it might be argued that the perceptions recorded here are already out of date. The new generation of teachers should be more computer aware than their predecessors, not only because of the wider use of machines in society in general, but also because an increasing number will have used computers as learners while still at school. Chapter 4, investigates the attitudes of teachers in training over a three year period with a view to assessing whether or not such students will act as facilitators to future information technology initiatives, or whether they will remain uneasy about the use of machines in schools.

CHAPTER 4

TEACHER ATTITUDES TO EDUCATIONAL COMPUTER USE

4.1 Introduction

This chapter will describe a survey of the attitudes of prospective and serving teachers to the use of computers in schools over a three year period from 1983/84 to 1985/86. The aim of this study is to assess the degree of support and the degree of resistance to the educational use of computers, as measured by the perceived usefulness of the machine in the classroom.

4.1.1 Background to the Survey

Previous studies of attitudes to computers (Chapter 3) suggest that there is a general acceptance of their usefulness in our lives, and, indeed, that they are generally held in positive regard (e.g. Ahl, 1976; Lichtman, 1979; Klassen et al., 1980). Lichtman's study, however, suggests that one group with reservations about the computer is the teaching profession. The study arose out of the considerable external pressures on educational establishments to prepare teachers for their role in a computer literate society. As an adjunct to the DTI initiatives placing computers in schools, the DES required LEAs to provide minimal computer awareness courses for the staff of participating schools. Participating colleges, however, were required to provide a minimum of 20 hours tuition for all students on initial or post graduate teacher training courses. The assumptions of such directives were that, unlike other innovations within education, there were specific basic skills of computer management, not accessable in general training, that teachers and students needed to acquire before any worthwhile educational innovation and evaluation could be undertaken. There was also perceived resistance to this expensive, technological innovation which needed to be overcome. Lichtman's (1979) study quantifies this resistance in the the USA at a time when computers were actively being placed in schools. He found that only 64% of his teacher sample thought that computers would improve education, compared to 96% of his educational administrators. These same teachers were also dubious about the usefulness of the computer as an aid in their own classrooms. Only 36% felt that a computer in their classroom would help them personally to be a better teacher.

Successful employment of computers in schools and colleges requires teaching staff to be persuaded of the relevance and general usefulness of the machine, to the curriculum in general, and to their own area of expertise in particular. Lichtman (1979) expresses an important concern arising out of his study: if administrators are far more positive to the computer than teachers will we find that a great number of machines will be purchased but that they will not be used? The educational and psychological literatures readily attest to the importance of the teacher as 'gate keeper' to educational innovation. Johnson (1980) states that computer literacy courses have unpredictable effects of on attitudes to computers, and he suggests that general public computer literacy is partially dependent on a computer literate teaching profession.

It is against this background that my college instigated a policy of compulsory computer awareness modules in all substantive initial and post-experience educational courses. Although such a policy affected all areas of the curriculum, seminars to appraise staff of the use of computers in school were poorly attended, and the policy met with considerable resistance within the teaching staff, a clear case of the 'gate keeper' acting as an inhibitor of change. This resistance came as no surprise and was not specific to this institution. Gredler (1985) offers evidence of covert teacher sabotage of computer use in the classroom and Turkle (1984) points out that attitudes to computers are highly charged in general. And as Swinton et al. (1978) have shown, even when teachers' attitudes are largely positive and encouraging towards the use of computers in schools, there may be considerable disparity in the degree and the nature of the use that they will initiate or allow in their classroom.

Initiating a computer literacy course for students whose interests might range from Fine Arts to Physical Sciences, and who taught ,or were training to teach, the full educational age range from 3 to 18+ , was viewed as a daunting task in itself. The added prospect of a largely negative response to the concept of computers in the classroom, as appeared highly likely after initial discussions with a wide range of the institutions own staff, only appeared to magnify the problem. In order to assess resistance to the computer awareness course, and to help in the development of that course, a survey of attitudes to the presence of computers in school was undertaken.

The underlying assumptions of the study were that attitudes to the use of computers would be related to a teacher's knowledge of the computer, his or her own area of expertise and, to the age-range of pupils taught. The research evidence on the match between knowledge and attitudes is inconclusive, as has already been pointed out. In this study knowledge was initially split into two components; self-reported experience of using computers and accurate general knowledge, rather than precise knowledge of computers as defined by Thomas (1976). The main study was conducted over a three year period with a new sample each year. As the level of knowledge of computers could be expected to increase with each successive questionnaire sample, because of the increasing profile of computers in our society, it was assumed that there would be a difference in attitudes between groups at each successive time phase.

The work of Beck (1979), Matthews and Wolf (1979) and Wilson and Trenary (1981), identifies a subject-expertise or interest component in the formation of positive attitudes to the computer. The pattern is not simply one of 'positive scientists versus unhappy artists.' Those electing to take computer courses are, unsurprisingly, the most positive in attitude. There then appears to be a continuum of appreciation from positive regard (mathematicians and technologists) to increasingly less positive feelings as expressed by business studies and arts students (represented by the historians in Beck's research). These findings are confirmed by Opacic and Roberts (1985).

The variable age-range was considered to be relevant because of the characteristics of students entering each level of the school system. Primary teachers might be considered to have a more child-centred rather than subject-centred approach to education. Secondly as computers, under the DTI scheme, entered secondary schools before spreading to primary schools, the level of expertise of teachers in the secondary school might well be greater than for primary teachers. However the extensive use of computing facilities for computer studies classes in secondary education may equally result in a situation where teachers, who wish to use the computer for non-examination orientated purposes, have even less contact with the machine than colleagues in primary schools.

Previous research suggests a difference in attitude to the computer across the sexes (Moore, 1985) but in this study, because no group had less than 75% or more than 90% female membership, there was no scope for an investigation of gender differences. On the basis of previous research, the nature of the sample suggested that attitudes to the computer would be at best cautiously favourable and possibly negative to the use of the computer in schools.

4.2 Method

A small pilot questionnaire was presented to 52 undergraduate students in their third year of a four year Batchelor of Education Degree (BEd) in the academic year 1982/1983. Subsequent refinements to the questionnaire were undertaken and a new questionnaire formulated and used as the test instrument for the current study.

4.2.1 The Sample

The survey sample consisted of 313 teachers, or teachers in training, all of whom were at the start of a short, compulsory computer literacy course. The survey was conducted over a three year period from the academic year 1983/4 until 1985/6, following the pilot study in 1982/83. The sample subjects were working in the full educational age-range and were categorised into three groups on age-range: workers with pupils in their Early Years (3-8 years old); Middle Years (8-12 years old); and Later Years (11+ years old including further education students). The sample subjects were enrolled on a variety of courses but were further categorised as students on the B.Ed programme, on the Post Graduate Certificate in Education (PGCE), or, as teachers (with a minimum of three years classroom experience) enrolled on a variety of in-service courses.

B.Ed. students constituted 59% of the sample with 18% PGCE and 23% teacher subjects. Approximately one third of the sample taught the Early Years age-range (32%); 48% were involved with the Middle Years; and, 19% were secondary and further education teachers (Later Years).All of the students were enrolled on substantive educational courses.

4.2.2 The Questionnaire

This questionnaire, designed to gather information on the perceived usefulness of the microcomputer in the classroom, can be considered to have two parts. The first two sections (Parts i and ii) collected biographical details on age-range taught, considered area of expertise (as measured by academic specialism studied during their training period), experience of using a microcomputer and awareness of the possible uses of a microcomputer (Table 4.4a). Information on the area of expertise of currently practising teachers varied from that outlined above if the teachers initial training was completed more than ten years prior to the study period. In these cases teachers were asked either to identify their current main teaching area, in the case of Later Years subjects, or, to specify their main areas of academic interest over the previous five years.

Table 4.4a

Assessment of Computer Knowledge of the Respondents to the Attitude Questionnaire: Part ii.

(Although subjects' were required only to indicate agreement to the statements below, annotation of the questionnaire was encouraged).

For what purposes have you used a computer?

As a programmer. (state language)
With children in the classroom.
For analysing data i.e. using a statistics package.
For computer games.
Word processing.
I haven't used a computer before.

Which of the following job descriptions could be performed by a computer?

A consultant doctor diagnosing the problems of patients.
A powerful typewriter and document organiser.
A large and efficient filing system.
A monitor of goods going into and out of a factory.
A controller of a firm's payroll.
A highly efficient calculator.
An expert geologist making decisions about where to drill for oil.
A translator for the EEC parliament's document department.

The third section (Part iii) of the questionnaire comprised 29 questions designed to assess attitudes to the use of microcomputers in education. The 29 questions included 13 out of the original 14 questions from the pilot study. The one question to be removed related specifically to teachers in training and was therefore not relevant to the wider sample. The wording of question ten, which referred to microcomputers caused some confusion in the pilot study, and was altered to refer to computers in the final survey. A number of students queried the term microcomputer and express no knowledge of this special equipment. It was therefore felt that the generic term 'computer' would best suit the needs of the study.

Table 4.4b

Individual Items for the Computer Attitude Questionnaire: Part iii.

III. On a scale of 1 to 5, where 1 = strongly agree and 5 = strongly disagree, consider the following statements.

1. Computers will radically alter the teacher's role over the next few years.
2. I can see very little use for computers in my subject area.
3. Computers will allow children more control over their own learning.
4. I think computer awareness courses for teachers and trainee teachers should be optional.
5. Computers can do little that cannot be done as easily and more cheaply by a teacher with good worksheets.
6. It is vital that the next generation become computer aware.
7. Computers are simply a new piece of technology to be added to the teachers growing armoury of visual aids.
8. I'm really excited by the opportunities this new machine opens up for teachers and pupils.
9. Computers will de-humanise the learning experience.
10. Many areas of the curriculum could benefit from the use of computers.
11. The computer is simply a new teaching machine which will program children.
12. The use of the computer will encourage child-centred learning.
13. The money being spent on computers could be used far more effectively elsewhere in education.
14. More able students make the greatest gains from using the computer.
15. Parental pressure is the reason we have computers in schools.
16. The computer will be a really useful addition to the teaching of:
    a. Art and Craft
    b. Drama
    c. English
    d. Humanities
    e. Mathematics
    f. Modern Languages
    g. Music
    h. Physical Education
    i. Religious Education
    j. Science
17. A teacher can do little useful work with one computer for a class of thirty children.
18. Computer games are not educational.
19. Most children would benefit from learning to program a computer.
20. The computer is best used to give individual practice in basic skills such as tables and spelling.

Questions were constructed on the basis of informal comments by teachers and student teachers with regard to the computer, identifying concerns such as possible impacts on the teaching/ learning situation (including changes in teacher /pupil roles and in the emphasis placed on mechanistic learning); child centred learning; the relevance of computer literacy within education and within society in general; and the cross-curricula relevance of the microcomputer (Table 4.4b). Although no formal sub-scales were defined, the concerns raised by our discussions appeared to fall into three groupings; relevance, the learning environment, and usefulness. A description and exemplar question for each question group is presented in Table 4.5a.

Table 4.5a

The question group descriptions and sample items for the questionnaire

Question group	Description	Sample item
Relevance	The extent to which teachers felt knowledge of computers to be worthwhile to themselves or to their pupils.	Most children would benefit from learning to program a computer. (+)
The Learning Environment	The effects of the use of computers on the teaching/ learning environment.	Computers will de-humanise the learning experience. (-)
Curricula Usefulness	The degree and extent of the contribution the computer is perceived to have across the curriculum.	Many areas of the curriculum could benefit from the use of microcomputers. (+)

Subjects' attitudes were measured by the degree of agreement each subject registered upon a five point Likert-type rating scale to a series of statements about the microcomputer in the classroom. Questions were structured so that statements which might be construed as demonstrating a positive attitude to the computer were randomly organised to elicit approximately equal numbers of scores at each end of the rating scale. A breakdown of the items on the questionnaire by question group and by direction (positive or negative wording) is presented in Table 4.5b.

Table 4.5b

Allocation of test items by question group and by direction (positive or negative wording) for the Computer Attitude Questionnaire.

	Test Items	
Question group	Positive	Negative
The computer and:		
Relevance to society and education	6 8 19	4 13 15
The learning environment	1 3 12	9 11 18 20
Curricula usefulness	10 16 a-j	2 5 7 14 17

4.2.3 Procedure

Subjects were tested in their course groups at the onset of the computer awareness module before any formal work with the microcomputer had begun. Subjects were informed that the purpose of the questionnaire was to gather information concerning teachers' perceptions of the usefulness of computers in the classroom. The survey information would be an aid to the structuring of the computer awareness courses in the college as it assessed the experience and knowledge of the groups and identified particular areas of interest and of concern within the groups. It was emphasised that attitudes to computers were often strongly felt and that, whether positive or negative, subjects own attitudes were very important to the future design of the course. All responses would be treated as confidential but to aid in the free expression of views subjects were told that, although the questionnaire requested the subject's name, they were at liberty to ignore this question if, for personal reasons, they felt strongly about identifying themselves. No subject exercised this option. Subjects were then requested to complete the questionnaire, taking care to answer all questions (except for the initial question on name). There was no time limit set and subjects took between five and fifteen minutes to complete the task.

4.3 Results

4.3.1 Scoring

The initial biographical material was used to identify the key groups considered during the analysis, along the two dimensions of age-range taught (Early, Middle and Later Years) and type of student (B.Ed., PGCE or practising teacher). Simple measures of experience of using a computer (possible score 0 to 5) and of awareness of the different possible roles of a computer (possible score 0 to 8) were recorded. To remove the problem of low frequency counts for some categories on these two measures, these scores were combined to give an overall score of computer awareness (possible score 0 to 13) in all subsequent analyses.

The 29 attitudinal questions all recorded a score of between 1 and 5 points on the rating scale. Seven subjects who failed to complete all of the sample questions were removed from the study.

4.3.2 Analyses

Item Analysis: An item analysis was performed on the data to assess the internal consistency, reliability and possible lack of variability of the test items, the criteria for the elimination of any test item (Dunn-Rankin, 1983). A summary of the composition and properties of the 29 attitudinal variables showing the mean and standard deviation for each variable; the Pearson *r* correlations of each item with the total score on all items; and, Cronbach's alpha reliability coefficient (Cronbach, 1951) are shown in Table 4.6.

The correlation of each item with with the total score on all items acts as a discrimination index for each item, high correlations indicating internal consistency and items worth retaining. On this criterion item fifteen should be eliminated as it falls below the 0.2 correlation level suggested by Nunnally (1967). A more stringent level of 0.3

(Youngman, 1979) questions the value of items fourteen and twenty. None of these items has a noticeably low variability nor do they record a low Cronbach alpha reliabilty coefficient.

Table 4.6

Item analysis of the twenty-nine attitudinal variables

Variable	Mean	S.D.	Corr. Coeff	Alpha Values
1. Teacher role	3.29	0.98	0.30	0.843
2. Use in my area	3.64	1.23	0.54	0.835
3. Child control	3.36	0.96	0.48	0.837
4. Optional courses	3.70	1.22	0.40	0.841
5. Worksheets	3.52	1.00	0.47	0.837
6. Next generation	4.22	0.97	0.36	0.841
7. Visual aid	2.96	1.13	0.32	0.843
8. Opportunities	3.27	1.05	0.66	0.831
9. De-humanise	3.14	1.10	0.52	0.836
10. X_curriculum	3.89	0.91	0.54	0.835
11. Teaching machine	3.87	1.00	0.45	0.838
12. Child-centred	3.57	0.88	0.48	0.837
13. Effective spending	3.30	1.00	0.54	0.835
14. More able	3.7	1.10	**0.27**	0.845*
15. Parental pressure	4.08	0.89	**0.17**	0.846*
16. Useful in Art	2.42	1.10	0.48	0.837
Drama	2.04	0.92	0.44	0.838
English	3.56	1.07	0.54	0.835
Humanities	3.22	0.99	0.52	0.836
Maths	4.51	0.72	0.39	0.840
Mod. Lang.	3.73	0.94	0.40	0.840
Music	2.84	1.11	0.48	0.837
P.E.	1.98	0.96	0.39	0.840
R.E.	2.43	1.01	0.54	0.835
Science	4.20	0.88	0.43	0.839
17. One computer	3.00	1.13	0.40	0.840
18. Games	3.87	0.95	0.37	0.841
19. Benefit to program	3.82	1.00	0.35	0.842
20. Basic skills	2.99	1.07	**0.29**	0.844*

For each variable: Min. score = 1; Max. score = 5; Mean score = 3.
Where 1=strongly agree and 5=strongly disagree.
Values in bold indicate items which fail on the criterion of internal consistency.
Variable 'descriptions' are abbreviations of the questions appearing in Table 4.4b

The questionnaire as a whole achieves a Cronbach alpha score of 0.844, indicating acceptable reliability, and a domain validity coefficient of 0.919. Youngman (1983) suggests that with intelligence or achievement tests validity coefficients of 0.9+ should be sought, but for the less easily quantifiable measures of attitude or personality, values as low as 0.5 might be acceptable, if other criteria are met successfully. In this case the 0.9 criterion has been met. It was decided, therefore, that although the removal of items fourteen, fifteen and twenty would increase the reliability (Cronbach alpha) of the questionnaire, the items had acceptable within-item levels of reliability and variability and that the overall questionnaire would be little improved by their removal. All twenty-nine items, therefore, went forward for further analysis.

The Correlation Matrix: The study sought to establish whether or not there was a relationship between teachers' and trainee teachers' attitudes to the use of the computer in school and it investigated the influence on attitudes of the following three variables: knowledge of computers; type of teacher (trainee B.Ed. or PGCE, or experienced teacher) over time. Further the study sought to establish factors which identified key attitudes to computer use, and, through the description and categorisation of teacher responses to the questionnaire, to establish profiles of teachers with varying degrees of enthusiasm for the use of the computer in schools.

Initial application of correlational techniques to the data confirmed that the items were not independent and that there appeared to be a small group of items, indicating negative attitudes to the computer, which were strongly inter-correlated. Negative regard can be identified clearly here. A much looser network of items, indicating positive attitudes to the use of computers in school, also became apparent with this analysis. Two multivariate techniques were used to tease out the relationships between variables indicated in the matrix (factor analysis) and to group or classify the respondents to the questionnaire (cluster analysis).

The Factor Analysis: Following the initial correlational analysis, the responses to the 29 questions on attitudes to the computer, were subjected to multivariate analysis. As no variables had been, or could be, identified as of particular significance, factor analysis, rather than multiple regression techniques were applied to the data (Youngman, 1979).

The initial factor analysis suggested an eight factor solution although the eigenvalues (the variance accounted for by any individual component) for factors seven (1.08) and eight (1.03) only just achieved the 'eigenvalues greater than one criteria' for the identification of factors (Kaiser, 1958). These eight factors accounted for 56.5% of the variance. As attitudinal factors are necessarily inter-correlated, an oblique factor solution was sought. Reference to the factor pattern matrix (Table 4.7a) for the eight factor solution enables the character of the factors to be specified and highlights the difference between the those factors exhibiting strong correlations.

It is apparent from the factor pattern matrix that a number of variables contribute significantly to several factors and that, particularly, factor eight shows no definitive variable. Rimoldi (1948) argues that the squared multiple correlation (SMC) of a variable with the other variables (an estimate of the communality or common variance: Dunn-Rankin, 1983) is a useful aid to refinement if a large proportion of the variables have low SMC values. A situation where the definition of factors might prove difficult. Rimoldi offers a level of 0.30 as a possible cut-off point for variable exclusion. Ten variables in all had SMC's of less than 0.30 but all of these variables contributed significantly to at least one factor in the eight factor oblique solution. All variables were, therefore, retained.

Table 4.7a

Oblique Eight-factor Analysis Pattern Matrix

Item	Pattern		Matrix		(salients only)			
1. Teacher role							**0.52**	
2. Use in my area		-0.22			0.23			-0.20
3. Child control						**0.49**		0.16
4. Optional Courses							-0.39	0.21
5. Worksheets					**0.50**			
6. Next generation			-0.23				0.29	
7. Visual aid			0.26			0.29	-0.33	
8. Opportunities			-0.20			0.20	0.20	
9. De-humanise					0.31			-0.15
10. X-curriculum						0.28		0.26
11. Teaching machine			**0.46**					
12. Child-centred						**0.58**		
13. Effective spending			**0.55**					
14. More able								0.24
15. Parental pressure			**0.52**					0.16
16. Useful in Art	0.39		-0.25					0.22
Drama	**0.66**							
English		0.36						
Humanities		**0.67**						
Maths				**0.63**				
Mod. Lang.		0.34		0.28	0.20			-0.14
Music	0.31			0.21				0.24
P.E.	**0.61**							
R.E.	0.38	**0.42**						
Science				**0.56**				0.17
17. One computer					**0.48**		0.17	
18. Games					0.24			
19. Benefit to program				0.26				-0.21
20. Basic skills			0.24		0.28	0.26		
Relative contributions of each factor to the overall solution (%).	19.5	15.4	14.5	14.0	11.2	11.1	8.0	6.4

Key items in bold
Variable 'descriptions' are abbreviations of the questions appearing in Table 4.4b

Table 4.7b

Description and Variable Specification of the Eight Factors from the Oblique Analysis

Factor	Description	Salient Variables	
Factor 1	Usefulness in the Arts	16b 16h 16a 16g	(16i removed to factor 2)
Factor 2	Usefulness in the Humanities	16d 16i 16c 16f	(2 to factor F5)
Factor 3	Irrelevance	13 15 11 8	(6 and 7 to F7; 20 to F5)
Factor 4	Usefulness in Sciences	16e 16j 19	(16f to F2; 16g to F1)
Factor 5	Non-useful/mechanistic	5 17 9 20 18 2	(16f to F2;)
Factor 6	Pupil's role	12 3 10	(7 to F7; 8 to F3; 20 to F5)
Factor 7	Teacher's role	1 4 7 6	(8 to F3; 17 to F5)
Factor 8	Generally positive with no clearly defining variable.		

Table 4.8

Oblique Eight-factor Factor Correlation Matrix

	1	2	3	4	5	6	7	8
1	1.00							
2	**0.74**	1.00						
3	**-0.34**	**-0.54**	1.00					
4	0.08	**0.53**	**-0.36**	1.00				
5	-0.27	**-0.46**	**0.84**	-0.26	1.00			
6	0.31	**0.68**	**-0.66**	**0.77**	**-0.56**	1.00		
7	0.32	**0.52**	**-0.59**	**0.47**	**-0.58**	**0.58**	1.00	
8	**0.74**	**0.66**	**-0.55**	0.10	**-0.45**	**0.37**	**0.45**	1.00
	1	2	3	4	5	6	7	8

Significant relationships p > 0.001 in bold
Variable 'descriptions' are abbreviations of the questions appearing in Table 4.4b

The matrix of factor intercorrelations (Table 4.8) shows that factors one, two and eight are highly positively correlated showing that a belief in the Cross Curricula Usefulness of the computer (factor eight) is closely related to an appreciation of the value of computers to the Arts (factor one) and Humanities (factor two) curriculum. Factor two is also strongly positively correlated to factors four, six and seven (Useful in the Sciences, Pupil's Role, and the Teacher's Role). The latter two factors are also strongly negatively correlated to factors 3 and 5 which stress the Irrelevance of the computer and its Non-usefulness/Mechanisation of education. No one factor was dominant in this eight-factor solution. The initial factor (Useful in the Arts) accounted for only 19.5% of the variance (Table 4.7a) and the next three most important factors each accounted for approximately 15% of the variance.

The magnitude of intercorrelations among the factors (Table 4.8) suggest that there are three general attitudes towards the use of computers in schools. The link between the Irrelevance of the Computer and its Mechanisation of the Learning Experience (Factors 3 and 5) is particularly strong and is in opposition to the general attitude seeing the computer as a force for change (factors 6 and 7 with associated factors 2 and 4). The third factor measures the Cross-curricula Relevance of the computer (factors 1, 2 and 8). This last group of factors shows no relationship with factor 4, Useful in the Sciences. This is not surprising, most respondents accepted that there was a use for computers in the Sciences, with only a hard core rejecting even this use. The acknowledgement of the relevance of computers in the Arts, however, requires a different perspective of the computer and its capabilities.

These three groupings of factors correspond well to the three-factor oblique solution (Table 4.9b), in which each factor accounts for between 30 and 36% of the overall variance (Table 4.9a). these groupings could well form the basis of key constructs in any subsequent research.

One unexpected finding of this analysis is the persistent correlation of the value of the computer in mathematics and science with the belief that the computer will allow children more power over the learning environment, with the consequent change and challenge to the teacher's traditional role. This is surprising because, although the Nuffield Science Project,

Table 4.9a

Oblique Three-factor Pattern Matrix

Item		Pattern	Matrix	(salients only)
1. Teacher role				
2. Use in my area			0.37	
3. Child control				0.36
4. Optional Courses				
5. Worksheets			**0.56**	
6. Next generation				
7. Visual aid			**0.44**	
8. Opportunities			**-0.51**	
9. De-humanise			**0.57**	
10. X-curriculum				
11. Teaching machine			**0.60**	
12. Child-centred				0.34
13. Effective spending			**0.55**	
14. More able				
15. Parental pressure				
16. Useful in	Art	**0.55**		
	Drama	**0.67**		
	English			0.35
	Humanities	**0.43**		
	Maths			**0.68**
	Mod. Lang.			0.51
	Music	**0.57**		
	P.E.	**0.65**		
	R.E.	**0.63**		
	Science			**0.53**
17. One computer				
18. Games				0.32
19. Benefit to program				
20. Basic skills			**0.42**	
Relative contributions of each factor to the overall solution (%).		36.4	33.6	33.0

Key items in bold
Variable 'descriptions' are abbreviations of the questions appearing in Table 4.4b

and similar ventures in Mathematics, have introduced a more explorative, child-centred approach to the Science curriculum, the general impression one gains talking to teachers is that within the Sciences the emphasis is on the structure of the subject, a mechanistic ticking off of sub-skills, rather than on individual child development. Indeed many primary teachers hand over the teaching of mathematics to a set scheme such as SMP, allowing it to dominate their classroom in a way they would find unacceptable in the Language-Arts curriculum. Although the children work at their own pace through the set exercises, the order and type of material is the same for all, unless the teacher tailors the scheme to suit the individual child.

Table 4.9b

Description and Variable Specification of the Three Factors from the Oblique Analysis

Factor	Description	Salient Variables
Factor 1	Usefulness in the Arts and Humanities	16b 16h 16i 16a 16g 16d
Factor 2	Non-useful/mechanistic	11 9 5 13 8 7 20 2
Factor 3	Useful in Sciences/ child control	16e 16f 16j 3 12 18

In summary, therefore, the factor analysis reveals the complexity of teachers' attitudes towards the computer. In the eight-factor solution there is no one dominant factor to account for a major proportion of the variance. An acceptance of the usefulness of the computer in the Sciences is strongly associated with an encouragement of a child-orientated curriculum with the advent of the computer. At the other end of the continuum is a general belief in the irrelevance of the computer and the potential for de-humanising the educational experience. The pattern is not a simple continuum, however, the factor identifying the role of the computer in the Arts stands alone. It appears not to be related to the more general debate of whether we fear the computer in the class or not, rather it is a question of the competence of the computer to add anything to the more creative and visual mediums, and is related to an appreciation of the non-number crunching functions of the computer.

The Cluster Analysis: One main aim of this study was to identify groups of teachers with well defined attitudes to the usefulness of computers in the classroom. Cluster analysis, a well documented agglomerative analytical technique for the identification of intrinsic structures within data (Dunn-Rankin, 1983; Youngman, 1979), was applied to the 29 attitudinal variables and four masked variables relating to subjects' biographical details (type of teacher, year of sample, age range taught and knowledge of computers). These masked variables were removed from the analysis and so did not contribute to the structuring of the clusters.

The application of cluster analysis to questionnaire responses, involves the rearrangement of the matrix of responses into a number of convergences or clusters on the basis of the similarity or distance matrix. Items which are most similar or which are not far apart are grouped together, and then they are reduced in stepwise fashion by forming new groups of similar items at each step, until a single grouping is identified (Dunn-Rankin, 1983). The analysis is designed to bring all items measuring the same construct, or grouping of teachers of similar attitudes in this case, together and to form clusters that are distinct one from another.

Youngman (1979) sounds a warning bell about the dominance of high-variance measures in a classification which can result in distortions because the similarity coefficient operates on all variables together. It is apparent that in the survey data some items are heavily weighted in one direction and there is, therefore, a risk of such distortion. In the light of this argument, the data for each variable were standardised about the mean of the variable. Analyses completed for non-standardised data produced comparable results to those from standardised scores and have, therefore, not been included in the study.

The relocation centroid method of clustering was used because of the sample size (cases > 100) in this particular investigation. This method demands an initial classification of the data, unlike Ward's (1963) least squares distance method which starts with individual cases. Although Wishart (1972) shows that different starting points, or initial classifications, can result in severe disagreements in the final classification, Youngman (1979) argues that random, rather than pre-selected initial classifications, are acceptable 'as long as the data are classifiable' (p. 130). The initial classification randomly assigned responses to one of fifteen groups, a far larger number of groupings than expected in the final solution. This is necessary as the early stages of relocation analysis may not be reliable.

The use of cluster analysis ensures a solution whether or not the data is inherently classifiable, thus it is necessary to validate the solution. This may be achieved by dividing the sample into two, if enough cases are available as in this survey (cases must be greater than the number of items to be clustered and this must hold for the half-sample), and re-running the analysis.

As has already been described, all subjects (306) answered 29 questions plus contributing information to the four biographical scores. There was, therefore, a complete data set available for clustering, although the four biographical scores were masked and not used in establishing the cluster solution. Analyses were completed for standardised data. A second analysis, using half of the original sample selected by an odd number pairing, was used as a test of the validation of the cluster solution, as recommended by Youngman (1979).

The Diagnosis of Clusters: The fusion graph (Figure 4.1a) shows two marked changes of slope at the one and three cluster solutions. Although such breaks indicate that relatively dissimilar groups have been combined and, therefore, the groupings before that fusion is more valid, Thorndike (1953) stresses that the lack of such a break does not necessarily mean that a bad classification may ensue. Nevertheless the graph does suggest that a two- or four-cluster solution would be worth further investigation, and this is confirmed by the dendrogram (Figure 4.1b). The dendrogram indicates a five-cluster solution is also a possibility but in the interests of parsimony this solution was rejected.

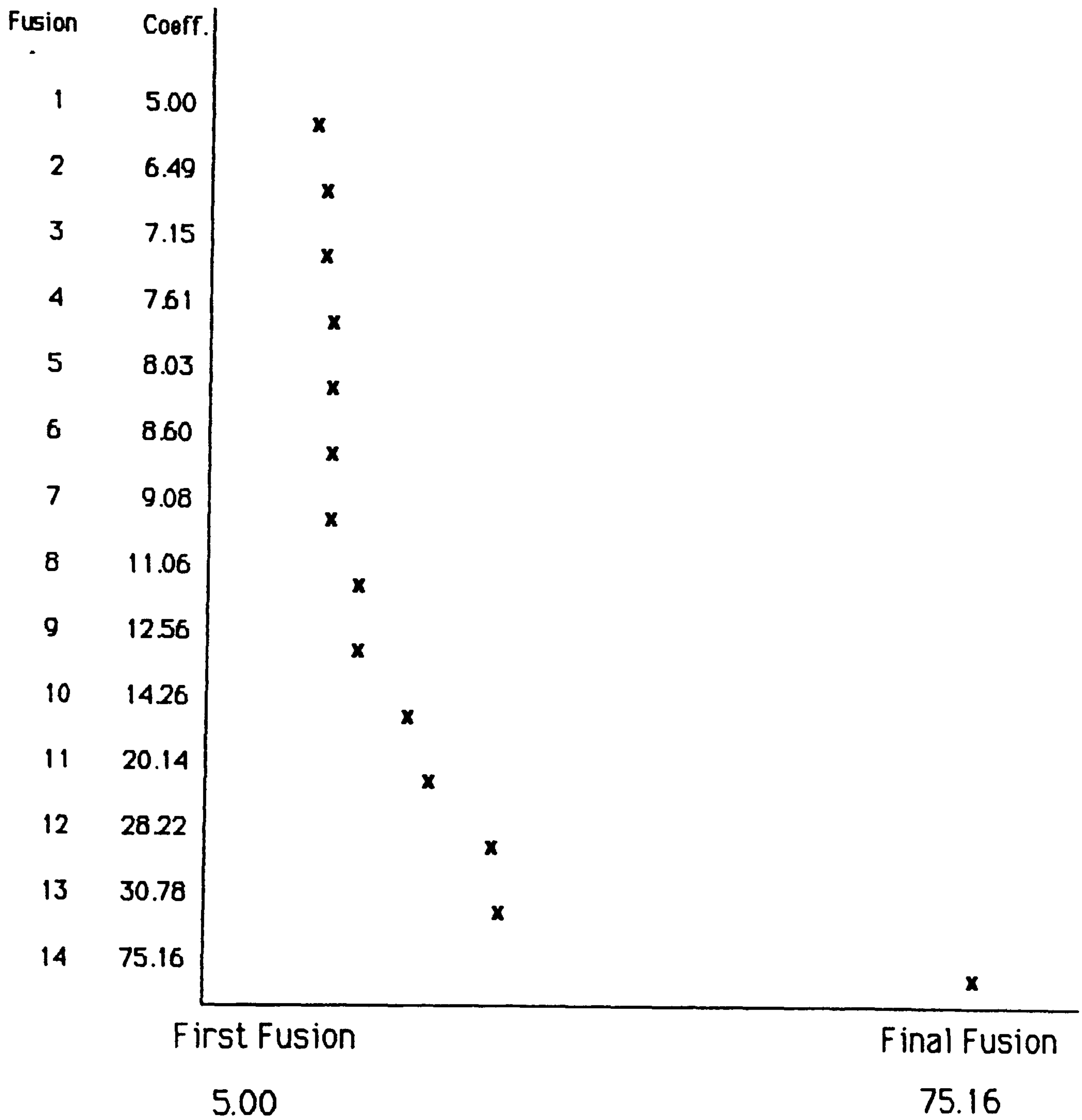
Table 4.10

A Comparison of the Membership of the Two- and Four-cluster Solutions (all data).

		Four-cluster Solution				
		C4.1	C4.2	C4.3	C4.4	Tot
Two-cluster Solution	C2.1	43	84	30		158
	C2.2	42		53	53	148
Total		86	84	83	53	

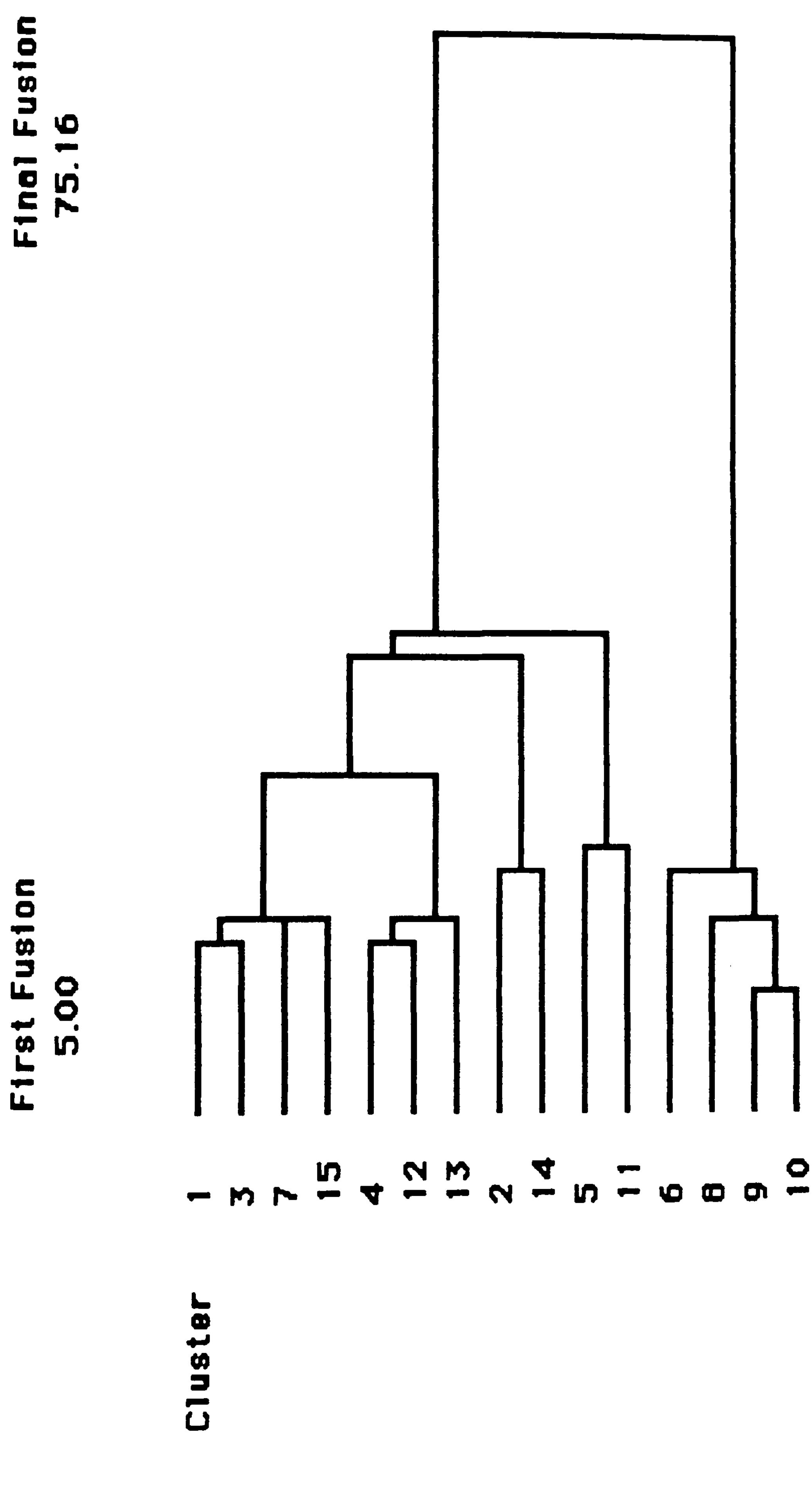
A comparison of these two cluster solutions (Table 4.10) shows that clusters C4.2 and C4.4 in the four-cluster solution are refined versions of the two cluster solution, representing the pro- and anti-computer groups respectively. Not surprisingly, no members of the original cluster C2.2 (anti in the two-cluster solution) cross-over and become members of the pro-computer group (cluster C4.2) in the four-cluster analysis. The same stability is present in the new anti-computer group, cluster C4.4. The new clusters C4.1 and C4.3 are composed of members from both of the original C2.1 and C2.2 clusters; C4.1 collecting equal numbers of subjects from the original pro- and anti-groupings, while C4.3 is weighted towards subjects from the anti grouping. These two new clusters are indicative of a greater variation of opinion than is revealed by the two cluster solution, indeed the composition of the groups suggest that there may be a continuum of opinion from positive to negative as Matthews and Wolf (1979) argued. The four-cluster solution was therefore selected on the grounds that the two-cluster solution is simplistic and that the four-cluster solution most adequately represents the range of attitudes expressed by the subjects.

Figure 4.1a



Distance plot for the relocation cluster analysis on the full sample. The breaks of slope occur after the ninth, eleventh and thirteenth fusions. This suggests that the six, four or two clusters solutions should be considered further.

Figure 4.1b



Dendrogram for the whole sample cluster analysis. A four cluster solution was selected in preference to the possible five cluster solution in the interests of parsimony and ease of interpretation.

The item groupings for the four-cluster solution are shown in Table 4.11. This profile chart confirms that the four cluster solution adds considerably to our knowledge of respondents' attitudes. Cluster C4.2 (84 respondents) and C4.4 (53 respondents) are highly suggestive of the extreme ends of a continuum. In cluster C4.2 twenty-five out of a possible twenty-nine item scores are significantly above the mean of the clusters, as measured by the Scheffé atypicality test (see Youngman, 1979), that is towards the more positive perception of the computer. No item scores are recorded as significantly below the mean of the clusters, for this cluster. A similarly strong negative cluster, cluster C4.4, records twenty-seven scores significantly below the mean of the clusters with no scores significantly above the mean.

Clusters C4.1 and C4.3 are clearly different from the two clusters expressing the ends of the continuum. Each is composed of a reduced number of items in comparison to clusters C4.2 and C4.4, and those items may be both significantly above or below the mean of the clusters. Cluster C4.1 comprises fifteen items, five expressing more positive views and the remaining ten below the mean of the clusters. Cluster C4.3 has twelve significant items, six of which are above the mean of the clusters.

The stability of these clusters can be measured by comparison with the half-sample analysis (Table 4.11). Although only a three-cluster solution is proposed, after recourse to the fusion graph and dendrogram (Figures 4.2a and 4.2b), there are, nevertheless, great similarities between the full and half-sample solutions. The strongly pro- and anti- computer groupings (half-sample clusters 2 and 3) are still readily apparent, with twenty-seven above mean of clusters scores in the former and twenty-three below mean of clusters scores in the latter. Again the pro- grouping has no below mean scores and the anti- grouping has no above mean scores. The third cluster in the half-sample is defined by eleven items, five of which are above the mean of clusters. This cluster is very comparable to cluster C4.1 in the main analysis. There is no comparable grouping to cluster C4.3 in the full sample solution.

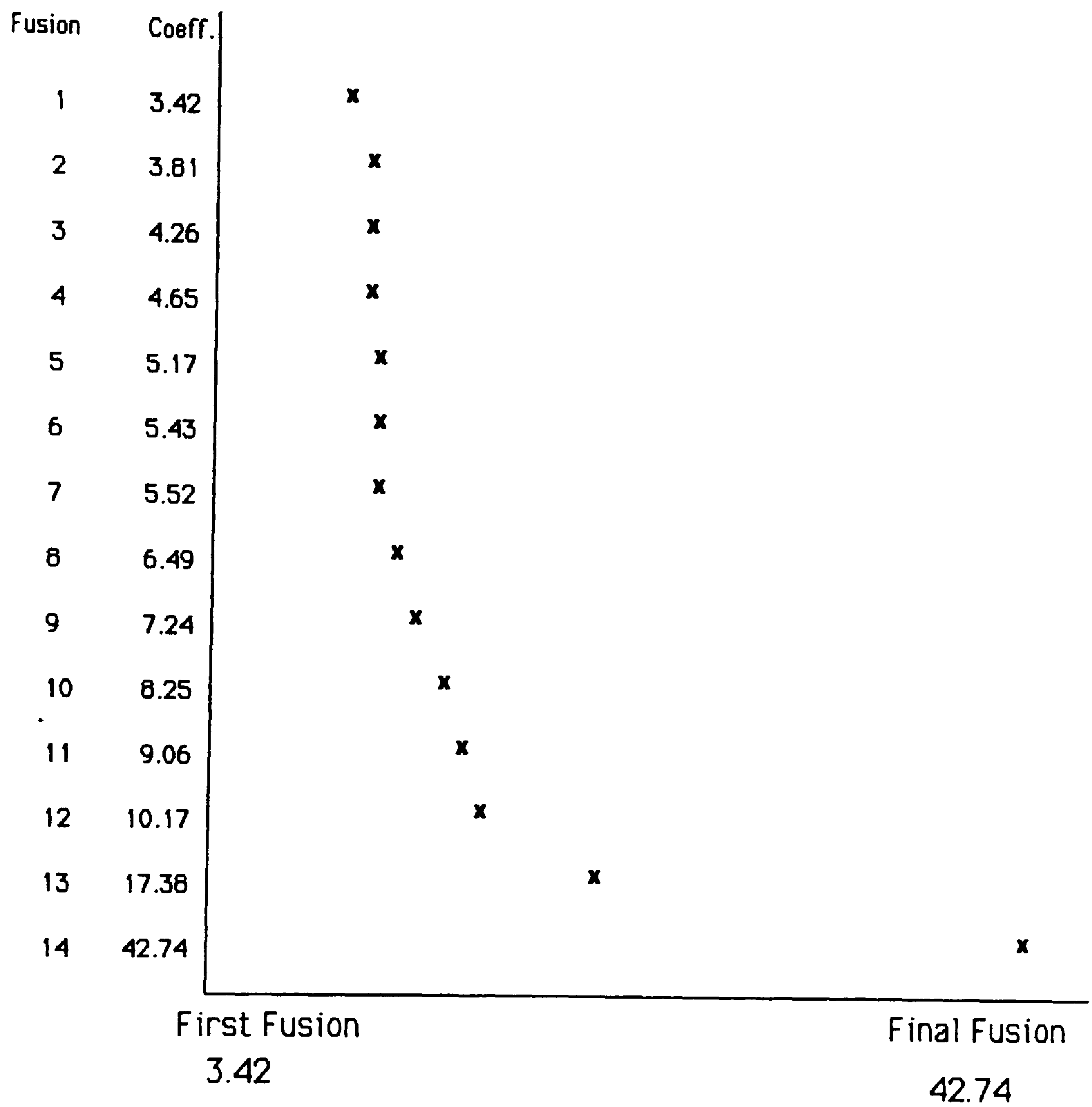
Table 4.11

Cluster Analyses for the Attitude Questionnaire: Standardised Full Sample and Half Standardised Sample.

Item	Standardised Full Sample				Standardised Half sample		
Cluster	C4.1	C4.2	C4.3	C4.4	hs1	hs2	hs3
M1				--			
M2							
M3		++				+	-
M4		+					
1. Teacher role		+		-			
2. Use in my area		++		--		++	--
3. Child control		++		--		++	--
4. Optional course				--		+	--
5. Worksheets		+	++	--		++	-?
6. Next generation	-?	++		-		+?	
7. Visual aid				--		+?	-
8. Opportunities	--	++	+	--		++	--
9. De-humanise		++		--		++	--
10. X-curriculum		++		--		++	--
11. Teaching machine		++	++	--	-	++	-?
12. Child-centred	--	++		--		++	--
13. Effective spending	--	++		--		++	--
14. More able	-	+				+?	
15. Parental pressure	--				--	++	
16. Useful in Art	++	++	--	--	++	++	--
Drama	++	++	--	--	++	++	--
English		++		--		++	--
Humanities		++	--	--		++	--
Maths	--	++	++	--	--	++	-?
Mod. Lang.		++		--		++	--
Music	+	++	--	--	++	++	--
P.E.	++	++	--	--	+		--
R.E.	++	++	--	--	++	++	--
Science	-?	++		--	--	++	--
17. One computer		++		--		++	--
18. Games	--	++	++	--	--	++	-?
19. Benefit to program	--	++	++	-	-	++	
20. Basic skills				--		++	

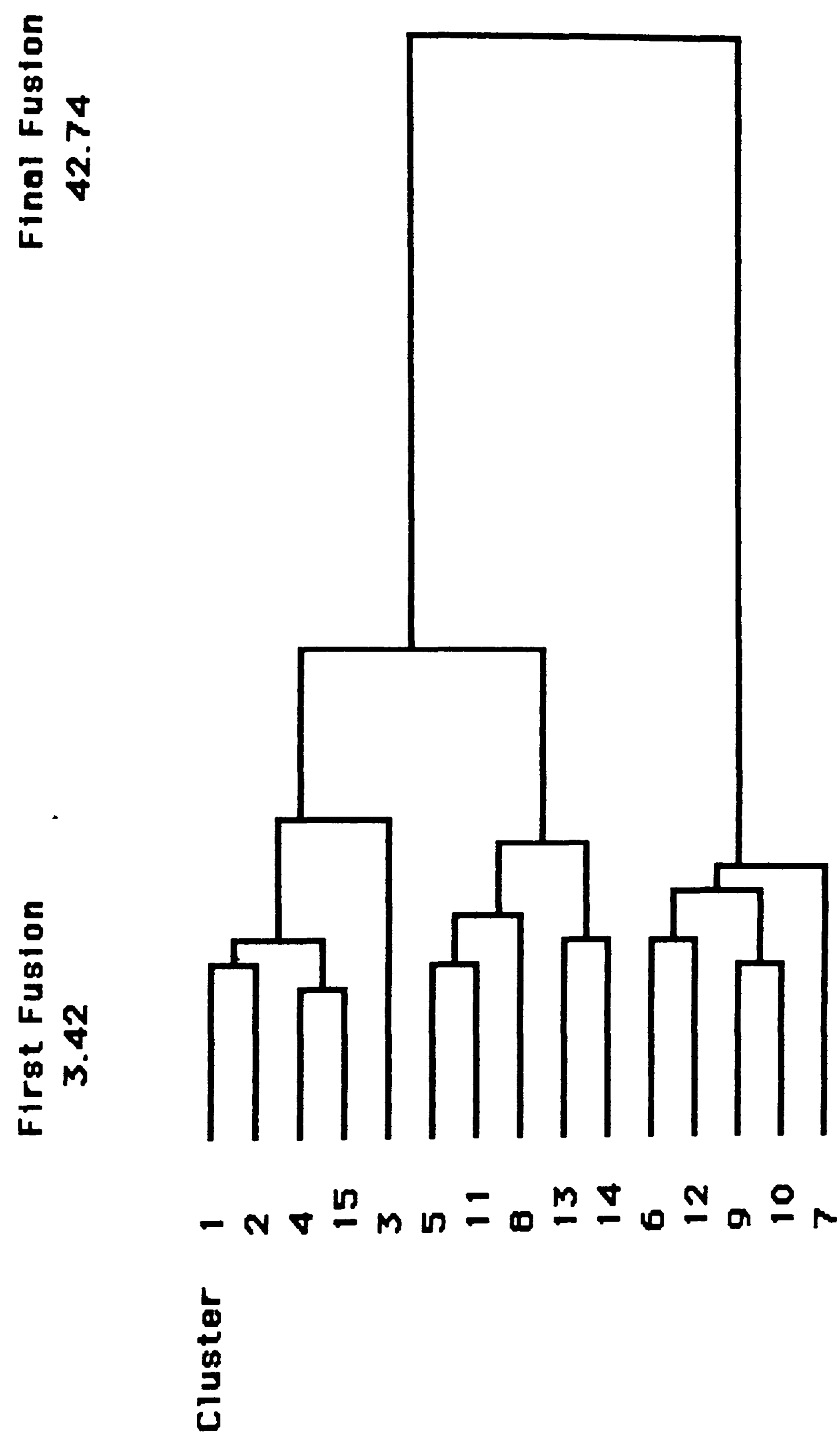
hs half sample
M 1-4 are the four biographical variables masked for the purposes of clustering.
+ or - indicates that the cluster is respectively above or below the mean of the remaining clusters as tested by the Scheffé atypicality test.
Variable 'descriptions' are abbreviations of the questions appearing in Table 4.4b

Figure 4.2a



Distance plot for the relocation cluster analysis on the half sample. The break of slope occurs after the twelth fusion. This suggests that the three clusters solution should be considered further.

Figure 4.2b



Dendrogram for the half sample cluster analysis. A three cluster solution was selected for further investigation.

The comparability of the full and half-sample solutions, particularly in the strength of the two main clusters, is indicative of a stable solution and the internal validity of the classification. The characteristics of the four clusters and their membership will now be described in detail.

A Description of the Four-cluster Solution: Before describing each of the four clusters in detail it is useful to note respondents' overall perceptions of the computer. In general the respondents were more positive than negative in their attitudes towards the use of computers in schools, as is shown by their responses to selected key questions (Table 4.12) and by the ratio of 4:1 positive to negative responses for the sample population (Table 4.13). Questionned on the relevance to the computer in their own area of expertise and across the curriculum in general, there is a strong positive vote by the sample as a whole. This pattern is confirmed for three of the four clusters (which include 83% of the survey sample). Only the fourth cluster deviates from this pattern, with members seeing little use for the computer in their own area and showing uncertainty of its value across the curriculum in general.

Table 4.12

Mean Response Scores on Selected Questions: Overall Sample and Cluster Means.

Question	Mean Response Scores				
	Tot. all	Clusters			
		C4.1	C4.2	C4.3	C4.4
2. I can see little use for the computer in my area.	3.64	3.79	4.14	3.78	2.40
6. It is vital for the next generation to be computer literate.	4.22	4.00	4.56	4.33	3.89
8. I'm really excited about the opportunites this new machine opens up for pupils and teachers.	3.27	2.94	3.96	3.54	2.30
10. Many areas of the curriculum could benefit from the use of computers	3.89	3.81	4.54	3.73	3.21

In cases were a low score represents a positive attitude to the computer the score is reversed so that in all cases the higher the score the more positive the attitude on the 1-5 Likert-type scale.

Strong positive attitudes are also expressed by the sample as a whole, and by each of the four cluster groups, concerning the relevance of computer-user skills. All groups expressed the need for future generations to be computer literate. This finding is somewhat paradoxical when compared to statements of interest towards the computer in the classroom (question 8).

Overall the sample is indifferent to the charms of the computer, although recourse to the clusters does show that subjects in clusters C4.2 and C4.3 are keen to use the computer while those in cluster C4.4 are not. Negative responses are recorded on only four questions, each relating to the usefulness of the computer in the Fine and Performing Arts. The group as a whole sees the computer if not as firmly Science based, then as of very restricted use in the Arts, and of qualified use in the Humanities.

The pattern of attitudes towards the computer can be seen in Table 4.13, which records the total number of items expressing positive, neutral or negative perceptions of the computer for each cluster. The dominant feature of this pattern is the strength of the pro-computer attitudes expressed by cluster group C4.2. On only one question does this group express a clearly negative attitude and that concerns the relevance of computers to the teaching of physical education. By comparison group C4.4 is less certain in its anti-computer views; there are an equal number of negative and neutral items plus four positive perceptions. The pro-computer items include a recognition of the usefulness of the computer in mathematics and science and the relevence of computer skills to future generations.

Although Table 4.10 suggests similarities between groups C4.1 and C4.3, as each has a membership drawn from both the pro and anti clusters in the two-cluster solution, they are in fact two distinct groupings, as is highlighted in Tables 4.11 and 4.13. Cluster group C4.1, although expressing positive rather than negative views overall, is composed of those people with rather weak views. The members of group C4.3, on the other hand, have firm ideas about computer useage and, although largely positive in approach, the group has certain reservations and is less euphoric than group C4.2 towards this new technolgy.

Interpretation of the Cluster-groupings: This analysis is based on the full sample of 306 respondents using standardised data. A summary of the biographical characteristics of the cluster groups is shown in Table 4.14. One initial hypothesis was that attitudes would become more positive towards the computer over time. This would be a reflection of the increasing environmental feedback to which successive sample groups would be exposed, resulting in the increased computer awareness of these later groups. This hypothesis was not substantiated by the Chi-square tests applied to the data. There was no effect of 'Year of sample' across the four cluster groups (X^2=0.45; df=3; n.s.). Level of computer awareness, as measured by knowledge of and use of computers, did influence attitudes, however (X^2=5.89; df=3; $p<0.001$). The members of cluster C4.2 were significantly more knowledgeable about the computer than members of the other three cluster groups (Table 4.14).

Table 4.13

Comparison of the Overall Nature of Responses to the Twenty-nine Questionnaire items for the Four Clusters and for the Sample as a Whole.

Cluster	Nature of Item Response		
	Positive	Neutral	Negative
C4.1	10	17	2
C4.2	22	6	1
C4.3	14	9	6
C4.3	4	13	12
Total Sample	16	9	4

A neutral response is defined as any mean response lying between 2.50 and 3.49.

The members of cluster C4.2 were also more likely to teach the middle or later years (Table 13), confirming the hypothesis that age-range taught would influence attitudes to computers (X^2=3.06; df=3; p<0.03). The distribution of teachers across the age-range taught did not vary significantly from the mean of the full sample for each of the other three clusters. The fourth hypothesis, that teacher-type would influence attitudes, was also substantiated (X^2=4.57; df=3; p<0.004). Group C4.4, the least positive group, contained significantly more respondents who were studying for a BEd. degree than any of the other groups (Table 4.14). There was no significant difference from the sample mean of teacher-type for clusters C4.1, C4.2 or C4.3.

Table 4.14

Biographical Details of the Membership of the Four Clusters

Characteristic		Response Mean for Clusters C4.1	C4.2	C4.3	C4.4
	N =	86	84	83	53
Teacher type: BEd. PGCE, Teacher.		1.7	1.8	1.65	1.28**
Year of sample.		2.28	2.23	2.34	2.32
Age-range taught: Early, Middle and Later.		1.26	1.64**	1.19	1.11
Level of Computer Awareness.		6.02	6.46*	5.88	5.74

Specific comparisons between groups using Scheffé's atypicality test.
* p< 0.05 ** p< 0.01
All scores are non-standardised means.

In addition to the biographical details (Table 4.14) entered into the cluster analysis, the survey also gathered details on the area of academic expertise for each member of the sample. In the light of the responses to question 16 a-j on the questionnaire, four areas of the curriculum were identified as producing different responses on the relevence of the computer to that area. They were the Sciences (including Mathematics); the Humanities (including English); the Arts; and, Modern Languages. The influence of academic area on attitudes was analysed using the Chi-squared test. This initial analysis showed no significant influence of academic area on attitudes (X^2=11.39; df=9; n.s.). The low sample size in Modern Languages suggested that a further amalgamation of data would be beneficial; the Humanities and Modern Languages groups were therefore combined (Table 4.14). This collapsing of groups was consistent with the groupings outlined by responses to the questionnaire. Subsequent Chi-squared analysis revealed a weak effect of academic interest on attitudes (X^2=9.89; df=4; $p<0.05$). Scientists are disproportionally represented in cluster C4.2, the group with the most positive attitudes to the computer, while students of the Arts are over represented in cluster C4.4 (negative attitudes). Cluster C4.1 has a proportional mix of all academic areas, but cluster C4.3 has proportionally more workers in the Humanities than other academic areas.

Table 4.15

Distribution of Sample Members (number of respondents) across the Four Clusters by Academic Area.

	Clusters				
Academic Area	1	2	3	4	Total
Sciences	23	29	19	12	83
Humanities and Mod. Lang.	42	40	48	22	152
Arts	21	15	16	19	71
Total	86	84	83	53	

Cluster C4.1: 'Neutrals' — Consists of 15 items; 5 items are above the mean of clusters, that is they express more positive views than the sample mean as a whole, with 10 items below the mean of clusters (Table 4.11). Overall this group expresses neutrality towards the computer, or at best a guarded positive attitude (Table 4. 13). The cluster is defined by the groups positive attitude to the use of the computer in mathematics and science, negative attitudes to its use in the performing arts such as drama and physical education and their neutrality to its use in art and religious education. The group is also neutral on such important issues as the promotion of child centred education, the benefits of programming and of spending money in this area. The biographical details (Table 4.14) shows that this group does not vary significantly on any of the four measures from the overall group mean. There is representative proportion of trainee to trained teachers, at all age-ranges, with a moderate knowledge of the computer and drawn from each of the sample years.

This group may be termed the 'Neutrals,' although a better description might be the 'I haven't any views' group. In some studies questionnaires are either designed to force such respondents to make a clear cut decision, or neutral responses, are removed from the study (e.g. Moore, 1984). The identification of a confused and irresolute group is important for training purposes, however, and the group's emergence from the study is seen as valuable data.

Cluster C4.2 'High Expectations'

Consists of 25 items all of which are above the mean of clusters (Table 4.11). This group is strongly in favour of the computer (Table 4.13). They are excited about the use of computers in schools, which they believe will alter education for the better, resulting in a more child-centred and child-directed education. They do not fear that education will become de-humanised or mechanistic as computers enter the classroom and are keenly aware of the importance of computing skills in general, and the benefits of programming in particular.

The non-mechanistic view of the computer is fused with beliefs about the value of the computer across the curriculum. The computer is not just a tool of Mathematics and Science, it also has a place in Modern Languages, English, Humanities and Music. The group is equivical about the computers role in Religious Education, Art and Drama and records its one negative response to the questionnaire over the place of computers in the development of Physical Education. Not surprisingly, the group as a whole values the contribution that the computer can make to their own individual areas of education.

The biographical details for this group (Table 4.14) indicate that they vary from the overall group means on two dimensions; age-range taught (X^2=4.85; df=3; p< 0.003) and level of experience with the computer (X^2=3.06; df=3; p< 0.028). In general the group members are teaching older children, with a disproportionate number of middle and secondary school teachers' and these 'teachers' are more familiar with the computer than the members of the other three cluster groupings. The group does not significantly differ from the mean on type of teacher; that is whether in training on a BEd or PGCE course or a practising teacher, nor is there any difference over the three years of sampling.

Cluster C4.3 'Conditionally Positive'

Consists of 12 items; 6 items are above the mean of clusters, that is expressing more positive views than the sample as a whole (Table 4.11). The group is generally positive towards the computer (Table 4.13) and excited about its role in education but that role falls in clearly defined areas. Whereas the group is strongly pro the use of the computer in Mathematics, Science and, to a lesser extent, Modern Languages (the latter two items do not contribute significantly to the cluster definition) they see no role for the computer in the Arts in general. The computer is a scientific machine but not a mechanistic tool. This group values programming skills but does not believe that the computer will program children. It is an adaptive tool more useful than worksheets and providing new educational opportunities in the use of computer games.

The members of this group are representative of the whole sample on all the biographical measures (Table 4.14) and were defined as 'Conditionally Positive.'

Cluster C4.4 'Anti-Computer'

Consists of 27 items all significantly below the mean of clusters (Table 4.11). The strongly negative attitude to the computer this portrays is somewhat softened by recourse to Table 4.13, which shows that only 12 out of 29 statements were negative and that there is a large measure of indecision in this group. They do not, therefore, represent a mirror-image of the views presented in cluster C4.2.

As stated earlier in this chapter, this group is somewhat of a paradox. Although they admit that computing skills are vital for the next generation and tend towards a positive response on the usefulness of programming, they appear unwilling to be involved with the computer. They see little use for it in their own area, although they are neutral as to its role across the curriculum. This is a surprising statement when we review the questions related to specific subject areas; only Mathematics and Science are deemed to provide a suitable setting for educational computing. Arts and Humanities are not going to find the computer useful, although there is indecision over the role of technology in English and Modern Languages. This division of subjects possible relates to a perception of of skills orientated teaching in these areas and the view that the computer is best suited to basic or low-level skills practice, as expressed by this group. The group feels that the computer will de-humanise learning. The responses to related questions on child-centredness or control versus programmed children are far less strongly expressed, however, and all fall within the neutral category.

The biographical details of this group (Table 4.14) show that they are disproportionately composed of BEd as opposed to PGCE or practising teachers (X^2=4.57; df= 3; p< 0.004) but that they are equally represented across the age-range and experience level.

4.4 Discussion

This study has two main research goals: to measure the attitudes of teachers to the use of computers in schools and, to identify the factors influencing the development of those attitudes. The initial expectation was that attitudes to the computer would be largely negative. This hypothesis was based on the findings of previous researchers (e.g. Lichtman, 1979; Johnson et al., 1981; Moore, 1985). This pessimism proved to be ill founded. The sample as a whole expresses positive attitudes four times more frequently than negative attitudes. The one area where there is an overall consensus on the weakness of the computer is in the usefulness of the computer in the Fine and Performing Arts. On key questions, such as the relevance of the computer to future generations, the full sample mean is positive. Even the most antagonistic group, as defined by the cluster analysis (cluster C4.4), accepts the computer's relevance to society, a finding in keeping with Lichtman's (1979) work.

It is also quite apparent that the 'High Expectations' group (cluster C4.2) are far more definite in their views than the 'Anti-Computer' group, or machine-phobics, who are undecided, or hold very weakly defined views, on nearly 50% of the questions. This highly positive group also includes 27.5% of the total sample compared to 17.3% of the sample in the Anti-Computer group.

Teachers in the 'High Expectations' cluster group are more knowledgeable about the computer than other groups, and more likely to work with children over eight years of age. They include more scientists than other groups but have strong representation from Humanities and Modern Languages. Workers in the Arts are under represented in this group but a notable proportion, 21% of all the artists, are highly positive towards the computer. Of the four main groups of teachers defined by the cluster analysis, two are predominantly positive in their views (comprising 55% of the total sample); one group is negative (17.3%), although even here indecision is more prevalent than negative statements; and, one group is dominated by indecision (27.7% of sample), although positive statements outweigh negative in a ratio of 5:1. These findings suggest a wealth of good will, or at least neutrality, towards the use of computers in schools and should be encouraging to anyone involved in computer literacy courses for teachers.

Further examination of the cluster groups is revealing. 'Neutrality,' or generally irresolute behaviour (cluster C4.1), is not confined by any of the four biographical details entered in the analysis or by the academic interest of the teacher. In common with diffusion of all innovations, there are laggards waiting to be convinced across the full spectrum of teachers. The term laggards is used here as a technical term from diffusion modelling.

The differences between the two pro-computer groups lie in the 'High Expectations' groups' (cluster C4.2) cross curricular view of the computer compared to the more limited scientific role of the computer outlined by members of the 'Conditionally Positive' cluster group (cluster C4.3). Whereas one might expect cluster C4.3 to be dominated by scientists reserving the computer for themselves, this is not so. This group had proportionally more workers in the Humanities than any other cluster. Conversely cluster C4.2, advocating the wider use of the computer, had a greater proportion of the scientists from within the sample although the Humanities are also well represented. The 'High Expectations' group is also weighted towards the upper end of the school-age spectrum and includes a greater proportion of post-graduates and teachers. It may, therefore, be surprising that the members of this group are most happy about the changing role of the teacher which must come with the their acceptance of greater child autonomy in a computer enriched classroom.

One question which it is necessary to ask about this 'High Expectations' group is, whether the members of the group are basing their decisions on knowledge of the computer or, whether their euphoria is ill-founded. There are two pieces of evidence to suggest that they are making reasoned judgements in the main. Firstly this group is significantly more knowledgeable about the computer than the members of the other three groups. This result tends to confirm the work of Anderson et al. (1980-1981)and Opacic and Roberts (1985) which suggests a link between computer experience and attitudes, rather than that of workers such as Frates and Moldrup (1980), who argue that attitudes are products of ephemeral world knowledge rather than formal contact with the machine.

The second piece of evidence is less tangible. In stating that the computer can be useful across a range of academic disciplines, the High Expectations group also highlight the non-mechanistic role of the computer, and the variety of ways it can be used in the classroom, which is suggestive of the need to move away from basic skills teaching with the computer. Indeed, additional comments added to the questionnaire by members of this group emphasis an awareness of the computers abilities and the wasted opportunities which might occur if the computer is resticted to low-level activities. For example, subject 261 declared that '<u>The computer can perform as a highly efficient calculator,</u>' but added the rider ' <u>but this would be a total waste of the resource.</u>' An acceptance of the more complex functions of the computer goes hand-in-hand with greater knowledge of the computer.

The final group, 'Anti-Computer,' is low on computer knowledge and has a higher proportion of students on BEd. degrees and those in the Arts than any other group. The preponderance of B.Ed. student teachers could possibly be a factor of age or maturity. They are certainly no less academically qualified than the teacher group, nor do they have less classroom experience than the post-graduates. Their antagonistic views are most clearly expressed on concrete issues such as the use of the computer in their own area or in specific areas of the curriculum such as Drama. They also react strongly to emotive words such as de-humanising. The paradox of their acknowledging the relevance of the computer in general, while expressing no personal interest or value in the the machine has already been mentioned. It appears to be a case of 'I know its good for me but don't expect me to get involved!' If Anderson <u>et al</u>. (1980-81) and the present study are correct, many of the members of this Anti-Computer group could develop more positive attitudes to the computer once they have more first-hand experience of the machine. One caveat would be that that experience was relatively trouble free and that it was relevant to the direct needs of the group (Anderson <u>et al</u>., 1980-81; Wilson and Trenary, 1981).

4.5 Summary

Factor analysis suggests that there are three groups of intercorrelated factors which can be used to identify the overall attitude to the usefulness of computers in schools, they are; Usefulness in the Arts and Humanities; Usefulness in Sciences coupled with a more child-centred education; and, a general view of the non-usefulness/ mechanistic impact of the computer on education. It appears that once one has accepted that the computer is useful in the classroom, a major dividing point comes in persuading teachers that this is not just a machine for the science or mathematics laboratory. The current practice of reserving the computer studies room in secondary schools for examination course classes will only confirm this view. It may well be left to the primary schools to break down this prejudice.

The study suggests that, while knowledge of the computer is seen as both relevant and worthwhile, and the predominant feelings towards computer use in schools are largely positive, there is an element of 'let's wait and see.' Negative attitudes are related to low computer awareness and, possibly, the lower maturity of some B.Ed. students, compared to post graduates and teachers. Key factors in the development of a negative attitude to the computer are a failure to see the range of uses to which the computer can be put and a general feeling that it devalues, in some mechanistic way, the learning experience. Coupled with these attitudes are the views that the computer provides low level educational inputs which are no threat to the flexible role of the teacher.

Positive attitudes revolve around the potential of the computer to promote more child-centred learning and its usefulness across a wide spectrum of the curriculum. A discussion of such uses is presented elsewhere (Underwood,1985; Underwood and Underwood, 1987). Where changes in the teacher's role are anticipated, they are viewed as beneficial, and linked to greater student autonomy. A division occurs between those who accept the computer as a tool for most curriculum areas and those who feel it is still largely a scientific tool.

Those expressing the most positive attitudes to the computer are over represented in the Sciences and under represented in the Arts, but not all scientists are positive and certainly many artists do appreciate the value of the computer. The more accepting attitudes of the teachers and post graduate students, compared to the initial degree students, was somewhat of a surprise. As many children are responding very positively to the computer in schools there was an expectation of a more enthusiastic response from the youngest 'teachers.' Those who were least positive in attitude, however, were also least knowledgeable about the computer. A finding which supports the need for computer awareness courses for all teachers. Neutrality or indecisiveness is not a function of any one type of teacher, all the initial experimental groupings contribute to this final group of subjects, who are characterised by their unwillingness to express a strong opinion on even the most contentious of questions.

The concern, which stimulated this study, of a predominantly disinterested and possibly hostile clientele entering compulsory computer awareness courses, has proved ill-founded. Nearly half of our sample expressed very positive views towards the educational use of the computer, while a further 25% come to the courses without any strong predjudices. Perhaps the most encouraging finding, however, is that those who reject the computer in the classroom base their opinions on limited knowledge. As their level of computer literacy rises there is every hope that more favourable attitudes may ensue, for even these subjects recognised the usefulness of the computer as a tool outside the classroom.

SECTION THREE: CLASSIFICATORY SKILLS

CHAPTER 5: CLASSIFICATION, ORGANISATION AND COGNITION

CHAPTER 6: DATA ORGANISATION AND RETRIEVAL BY YOUNG CHILDREN

CHAPTER 7: THE ROLE OF THE COMPUTER IN DEVELOPING CHILDREN'S CLASSIFICATORY ABILITIES: INFORMATION-HANDLING PACKAGES IN THE CLASSROOM

CHAPTER 8: THE USE OF INFORMATION-HANDLING PACKAGES IN SCHOOLS: TEACHER AIMS AND CLASSROOM REALITIES

CHAPTER 9: THE ROLE OF THE COMPUTER IN DEVELOPING CHILDREN'S CLASSIFICATORY ABILITIES: TUTOR PROGRAMS IN THE CLASSROOM

Introduction

The Role of the Computer in Developing Children's Classificatory Abilities

The work reported here investigates the potential influence of classroom computers on the development of children's cognitive abilities. Specifically the research question asked is 'Can the use of classroom computers, with appropriate software, be an effective stimulus to children's acquisition of classificatory skills?'

Chapter 5 discusses the importance of classificatory skills in human cognitive development, and sets the later empirical reports in a general psychological and educational context. The empirical data relates to work with young children in the upper junior age-range (9-11 years old), with the exception of the case studies reported in Chapter 8. In this study the full school age-range was explored (5-18 years of age).

Chapters 6, 7 and 8 report a series of investigations into the use of computer-based information-handling packages in the classroom. The four experiments, reported in Chapter 6, investigate the influence of the pre-defined structure of a data-base on the user's organisation of information within that structure, and the user's retrieval of information from it. The key question here is 'Do young children have an appropriate range of organisational structures available to them in order to facilitate the effective use of computer data-bases?' This work draws heavily on the investigations of Durding, Becker and Gould (1977) and Brosey and Shneiderman (1978); both of these research groups worked with adult subjects.

Chapter 7 reports the results of a factorial design experiment to investigate whether or not children's classificatory abilities can be enhanced through the children's involvement in information-handling tasks, and whether that enhancement, if any, is further encouraged by the use of computer-based information-handling packages. The empirical investigation supported the argument that such computer-based learning is effective. Any performance gains recorded were considered in the light of similar but non-computer-based teaching and learning strategies. The children used two information- handling packages. The use of such programs is goal-orientated and highly structured, and encourages the active participation of the children, and can be considered to be an example of Ausubel's (1968) 'advanced organiser' theory of instruction.

As with all classroom manipulations the caveat must be that any performance gains are possible under appropriate circumstances, but they cannot be guaranteed. In Chapter 8, an analysis of eighteen case studies of the use of data-bases in the classroom is presented. Ostensibly this analysis was to ascertain whether the computer was used in these classrooms in such a way as to encourage the practice of classificatory skills, through the active participation of children in data organisation and retrieval. The claims that the use of information-handling packages would lead to a more investigative approach to learning were also scrutinised. The study goes beyond this, however, questioning current developmental learning theories and presenting illuminating insights into children's thinking.

In Chapter 9 the study returns to the question of the effectiveness of the computer in stimulating children's classificatory ability, already discussed in Chapter 7. The two experiments (Experiments 6 and 7) reported here follow the empirical procedure of Experiment 5, but in each case the software chosen operates under a different instructional style. In Experiment 6 the children were introduced to a tutoring program, which operated under a games format. The program was designed to encourage classificatory skills through practice with immediate feedback. This program can be thought of as providing a traditional mode of instruction. In Experiment 7 children were introduced to a design program based on

Edward de Bono's (1978) concept of lateral thinking. This program places a minimal structure on children's activities, but encourages novel mental manipulations of concepts, and is suggestive of Piaget's 'guided self-discovery' theory of learning.

The final section in this chapter compares the findings from Experiments 5, 6, and 7 and considers the relative effectiveness of different instructional styles, presented by computer for cognitive development.

CHAPTER 5

CLASSIFICATION, ORGANISATION AND COGNITION

This discussion will consider the importance of classificatory skills for human cognitive development. This theoretical chapter will therefore provide a general psychological and educational context for the empirical investigations which follow.

5.1 Categorisation: A Key Skill

Categorisation skills allow the reduction of environmental data into a hierarchy of classes by discrimination, abstraction, generalisation and organisation of common elements or crucial aspects of stimuli. Categorisation is an essential cognitive ability in helping with perceptual organisation, in eliminating the need for constant learning, and thereby, in aiding decisions about necessary actions. It is an ability which provides economy of mental effort, and efficiency in learning.

There is a considerable research literature on the importance of catagorisation skills in the development of human thought. The work of Bruner, Goodnow and Austin (1956) suggests that categorisation skills are the key to efficient information storage and retrieval in human memory. They listed five benefits of forming categories:

1. A reduction in environmental complexity - For example the average individual can discriminate between seven million colours. This feat is not achieved by the careful learning of each individual colour, nor by giving a specific name to each, it is accomplished by grouping

like shades together.

2. Identification - Recognition of a stimulus occurs when we can classify it into a familiar category such as animal or fruit.

3. A reduction in the need to learn - A consequence of these first two benefits is that we do not need to be taught about novel objects because if we can classify them we can use our knowledge of other category members to come to an understanding of the properties of the novel stimulus.

4. Appropriate action - Categorisation allows us to decide how to respond to a novel stimulus. A lion and a domestic cat are both animals but they can be further classified along the dimension dangerous and non-dangerous, and such a classification will define the appropriateness of stroking the animal.

5. Organisation of knowledge - Categorisation allows us to relate categories one with another to form a hierarchy of concepts. "That children and adults group discriminately different things and treat them as 'the same' or 'alike' is hardly debatable." (Olver and Hornsby, p. 68, 1966). This is a necessary act in order to make sense of the overwhelming amount of data impinging on the individual from the environment. This discriminatory act is one of 'equivalence -making' which, Olver and Hornsby have shown, is largely a function of learning.

The evidence for the use of classificatory criteria in organising and retrieving information is well established. Bousefield (1953) found that when asked to learn and recall randomised lists of categorisable words, subjects ignored the order of word presentation, tending to recall words first from one category and then another. The subjects appeared to be using general category labels as retrieval cues in completing the task. The importance of category labels in such a task, was confirmed by Tulving and Pearlstone (1966). They found that subjects for whom the category structure was made explicit during the learning task exhibited higher levels of recall than subjects who were not similarly cued.

Further evidence of the potential importance of organisational structures upon learning comes from Bower, Clark, Lesgold and Winzenz (1969). They devised a set of 112 words which could be hierarchically organised into four main categories. Two groups of students each received four presentation trials of the target words which they were asked to recall after each presentation. The first group received a randomised ordering of all 112 words on each trial. The second group received a word list which made explicit the hierarchical structure of the data. The results of this experiment emphasised the importance of organisational structures for learning, students in Group 2 recalled an average of 100 words after the final trial compared to a mean of only 65 words for Group 1. Effective learning is, therefore, demonstrably dependent upon effective organisation.

In classifying our world we are in fact developing concepts which, Bransford (1979) argues, we should view as tools to organise and clarify new experiences. Mosher and Hornsby (1966) state that one of the most characteristic features of seeking information is that we must sift alternatives to develop selection criteria, in order to decide what is relevant. Alternatives may be 'ready made' but often individuals not only have to choose between alternatives, they also have to invent or construct those alternatives. This is no easy task. Bransford argues that many potential groupings of conceptual features are relatively arbitrary and that individuals can construct classifications based on such arbitary concepts. When, however, those concepts are meaningfully related to other knowledge and purposes, the processes of concept formation and identification may be facilitated. Tulving (1962) has shown that even when no obvious relationships existed between stimuli, those learners who imposed their own organisational structure onto word lists, proved to be more effective learners, recalling greater numbers of words than their non-organised counterparts.

Giboin and Michard (1984) found that the development of programming skills by children (11 - 13 years of age) were facilitated by the use of FLIP, a programming language which encouraged the learner to think in a hierarchical manner. The use of this program not only stimulated top-down processing and modular development, but it also encouraged the children to concentrate on the semantic features of programming rather than on the syntactic details.

The development of classificatory abilities underpins logical thought but it is also relevant in the development of basic skills of reading. Turner, Skullion and Whyte (1984) have shown that good readers have well developed classificatory skills which allow them to construct a flexible and conceptually organised internal lexicon. Although their data are correlational, they argue that reading involves the selection and organisation of symbolic stimuli into units, and that this is achieved through superordination. Poor readers are not only less skillful at classificatory tasks, they also show a reduced correlation between reading and various tests of categorisation, and a less well integrated pattern of abilities than their more able counterparts. This lack of classificatory skills in poor readers results in an inefficiently organised lexicon and underdeveloped word recognition skills.

5.2 Defining Categories: Effects of Memory Organisation upon Memory Retrieval

It has been argued that the organisation of knowledge is the key to problem solving and thus to the individual's successful adaption to his world. This research emphasis on knowledge structures is underpinned by an extensive literature which has supported two main types of models of semantic memory: network models, based on the relationships between elements; and feature models, in which memory is organised by the identification and grouping of features.

5.2.1 Propositional networks

The computer model of Collins and Quillian (1969, 1972), which simulated aspects of human thought, assumed a hierarchical organisation of semantic memory constructed from: units, words representing things or subjects; properties, of a word or subject; and pointers, ties marking the relationships among units and properties. Within the hierarchy information is differentiated, and the properties of a unit at one level apply to all related units at the next lower level. In their hierarchy of animals, Collins and Quillian suggested that the property 'has wings' would be stored with high level unit 'bird' and not with the lower specific units 'sparrow' or'canary' although they both share this attribute. Therefore, characteristics of all birds are stored at the bird node and only properties unique to sparrows and canaries are stored with these specific bird names at a lower level of the hierarchy. This parsimonious storage of information they termed cognitive economy.

On the basis of this model, Collins and Quillian made predictions about the efficiency, measured by retrieval reaction times, of an individual's ability to search the memory store and answer a series of category questions eliciting a yes/no answer. They found that questions within a level, such as 'Does a canary sing' were answered more rapidly than 'Does a canary fly.' In the first sentence all the required information for verification was stored with the term 'canary,' but the latter question involved accessing information about flying, a property of most birds which, under the rule of cognitive economy, was stored with the higher level unit 'bird.' A question such as 'Does a canary have skin?,' spanning three levels of the hierarchy, elicited the slowest reaction times of all. Collins and Quillian argued that these differential response times were a product of the category-size effect: reaction times increased as the size of category, or number of units subsumed under a category, increased. These findings were of particular significance in that they emphasised the fact that all knowledge is not equally accesssible, and suggested that the nature of the knowledge structure in memory could predict the ease of information retrieval.

Collins and Quillian based their theoretical structure on the concepts of cognitive economy and upon a strict, logically based hierarchical store but subsequent research has questioned these assumptions. Experiments by Rips, Shoben and Smith (1973) showed that words such as 'mammal' evoked slower responses than 'animal' when linked to the term 'horse,' despite the fact that 'mammal' is logically closer to 'horse' in the hierarchical category structure. Conrad's (1972) attempted replication of the Collins and Quillian study failed when she controlled for the familiarity or the frequency with which a property was associated with a category unit. Indeed she found that familiarity was the main influence on response times. Rosch (1973) found that processing time was faster for typical category examples such as a robin than for atypical examples, such as a penguin.

The research data suggest that the rules governing cognitive economy put forward by Collins and Quillian need some modification. The basic tenet remains that queries involving properties not stored with a concept take a relatively long time to resolve because they require inferences to be made from information stored at higher levels of the hierarchy. If, however, a fact about a concept is frequently encountered, it will be stored with that concept even if it can be inferred from a node higher in the network, and this increasing frequency of association will result in rapid verification of queries.

5.2.2 Feature differentiation

Landauer and Meyer (1972), while replicating the category-size effect, postulated a second explanation, that of feature sets. They argued that the higher up the hierarchy a search takes place, then the greater number of features that have to be checked, the consequence of which is an increase in processing time required to reach a decision.

The feature matching explanation was extended by Rips et al. (1973) and Smith, Shoben and Rips (1974), in which they argued that concepts are characterised by both defining and characteristic features. Defining features are those which must be true of a concept, for example birds must have feathers. Characteristic features are not inviolate, however. Although most birds can fly, a penguin which uses its wings as flippers is nevertheless a bird. They argued that, when making category decisions of the type used by Collins and Quillian, both defining and characteristic features would be called into operation and that, in the case of true statements, response times would decline with increasing feature overlap. This was confirmed when the rapid response times recorded for comparisons of 'canary' and 'bird' were not matched when 'penguin' and 'bird' were similarly compared. They argued that on both defining and characteristic features, the overwhelming evidence confirms that a canary is a bird, but similar comparisons for penguin result in discordant evidence, and a second stage of processing, involving defining features only, needs to be invoked to resolve the problem. This model also accounted for the relative rapidity with which individuals responded to false statements such as 'a canary is an apple' compared to 'a canary is a robin'. The former statement was rapidly rejected as there was so little overlap between features but the latter pairing had many overlapping features which forced the individual to a second comparison on defining features only, again consuming processing time.

5.2.3 Schemata

The model of semantic memory put forward by Collins and Quillian is essentially a propositional network. Anderson (1985) states that, useful though these structures are, there are features of our knowledge which are too complex to be represented by such structures. Under these circumstances propositions cohere together in large order units called schemata (Bartlett, 1932; Rumelhart, 1980; Schank, 1980). The schematic representation of any object is defined not only by the attributes that the object possesses but also by the specific value associated with each attribute. A schema represents our knowledge about how properties tend to fit together to define objects (units) or how events tend to go together to define episodes. The emphasis here is on the word 'tend' for, although placing values in a schema will often specify typical categories, this is not always so. Anderson cites the example that although houses are typically built of wood or brick this does not exclude the possibility of a cardboard construction. To be able to predict what goes with what is vital if we are to operate successfully in our environment, but one prediction from the schematic structure of categories is that they will not have fixed boundaries.

5.2.4 Natural categories

Rosch in her seminal work on category structure (Rosch, 1973; 1975; Rosch, Mervis, Gray, Johnson and Boyes-Braem, 1976) has contributed much to the understanding of natural categories. Earlier work in this field was based on the Aristotelian strictly hierarchical superordinate-subordinate structure, in which, "the categories are logical, clearly bounded entities, whose membership is defined by an item's possession of a simple set of critical features, in which all instances possessing the critical attributes have a full and equal degree of membership" (Rosch, 1975, p. 193). Superordinate categories are differentiated by a paucity of shared attributes, for example furniture and vehicles share the attributes of inanimacy and being made or used by people, but little else. At the subordinate level there is a high degree of overlap as between arm chair, rocking chair and sofa. Rosch, however, argued that many natural categories are not of this type, but are organised around prototypic exemplars. Potential category members may vary in their distance from, and number of shared attributes with, the protypical member. Category membership is, therefore, not absolute but a matter of degree, dependent on the match to the prototype.

Rosch's research provides empirical evidence of a level of categorisation lying within the Aristotelian structure, which is of special psychological significance. This basic level of abstraction in a taxonomy is the most important, in the sense of most useful, for categories at this level carry the most information, possess the highest cue-validity and are the most differentiated one from one another. At the basic level, objects share a maximum number of attributes within the category, while sharing a minimum number of attributes with objects in contrasting categories. They are thus the first names we learn, they tend to be used in identifying objects and are the most generally useful in language. For example faced with a specific chair few people would name it as furniture (superordinate category label) or kitchen chair (subordinate), rather they would use the basic level label, chair.

Support for the extraction of the basic level category from the super and subordinate division comes from the work of Schvaneveldt, Durso and Dearholt (1985) on network scaling. They found that basic level concepts, as defined by Rosch, tended to produce a star-shape pattern of links. In their directed network, each concept had both an 'in-degree' and 'out-degree.' By 'in-degree' they meant the a number of directed links terminated on a concept, and the 'out-degree' referred to the number of directed links initiating from the concept. The sum of these two divided by the total number of links in a network gave the index of 'starness.' Superordinate categories tended to have indexes of a round 0.50 but basic level categories had an indices approaching unity.

Rosch's emphasis on the importance of prototypes is supported by experiments designed to teach new concepts (Posner and Keele, 1968, 1970; Franks and Bransford, 1971). In each of these studies subjects were presented with sets of visual patterns which were examples of particular concepts. For example, a prototypical pattern of nine dots, representing an isosceles triangle, was distorted by moving several randomly chosen dots in the vertical or horizontal plane to produce a number of nine-dot patterns (Posner and Keele, 1968,1970). Subjects were presented with four distorted patterns of three different prototypes and asked to classify each of the twelve patterns into one of three groups. Without access to the prototype the subjects learnt to correctly categorise the stimuli. Subjects then presented with the task of classifying stimuli defined as 'new', but including both previously seen and unseen patterns plus the group prototype, correctly classified the 'seen' stimuli about 87% of the time compared to a commendable 75% correct categorisation for unseen stimuli. However, the prototypes, which had not been previously presented, were classified as easily as the seen stimuli. The results suggest that , by averaging the characteristics of the distortions, subjects had created prototypes in their own memories and classification had taken place by matching stimuli to that prototype. In the Franks and Bransford (1971) study there was no difference in the rate of success in recognising old and new patterns, but subjects were more confident about having previously seen a pattern if it differed by only a small amount from the prototype. This result confirms that subjects in these tasks were learning a prototype.

The use of such prototypes in every day life is exemplified by Miller's (1980) successful prediction of the winner of the Miss America beauty contest, one year, by the process of averaging the characteristics of winners from the previous twenty contests. Again it appears that the judges of such contests have a prototypical or ideal image of a beauty queen in their minds.

Both in the laboratory and in our everyday world there is clear evidence that we evaluate category membership, such as prospective beauty queens, by the distance from the prototypical case. It is the family resemblance, not rules of function, that holds a category together. Wittgenstein (1953) argued against the idea that concepts can be represented in terms of defining features, citing the example of the category 'games'. There is nothing common to all games, yet we still develop the concept of the game. He argued that such a concept has a 'family' of meanings in which members of the family may look similar but yet lack a clear set of defining features common to all.

Rosch (1975) has suggested that words such as 'car' and 'bird' are represented in the cognitive system by a core meaning which is the prototypical instance. Natural categories have an internal structure which is composed of that core meaning and the family resemblances which are stored at some distance from the prototype. For example the category 'birds' has a typical member 'sparrow' and a non-typical member 'penguin.' The latter shares fewer attributes, or has a low family resemblance, to the prototypical bird, in that it swims but does not fly, than does the sparrow. Similarly a Ford Escort is a typical car while the sinclair C5 is atypical, and is viewed by the public at large, and indeed the liscensing authorities, as more akin to a bicycle or motorised toy.

This fuzzy boundary to class membership, the lack of Aristotelian absolutes in the definition of categories is supported by Lakoff's work (1973) on linguistic 'hedges', devices used to express degrees of class membership. Terms such as 'loosely speaking' used as in 'loosely speaking, a chicken is a bird' reflect the non-absolute nature of category membership. McCloskey and Glucksberg (1978) looked at people's judgements as to what were, or were not, members of various categories. They found that although there was a large degree of overlap between the decisions on class inclusion made by their thirty subjects, differences did occur. Terms such as 'stroke' were classified equally often as a disease and as not-a-disease. Interestingly, the disputed items such as 'stroke' were often reclassified by the same subjects when re-tested one month later. Thus category boundaries not only differ between subjects, individuals may provide different resolutions to a classificatory problem over time.

Bateson (Schwartzman, 1978) further highlighted the subjective nature of natural categories, when he argued that the obverse of the class of 'chairs' was not simply the class of 'not chairs,' there was also a class of 'improper not chairs:' a 'table' is a 'not chair' but 'tomorrow' is an 'improper not chair.' He argued that in defining a class, the members of the 'not class' must always be of the same logical type as the members of the class. In the above example 'tomorrow' is not of the same logical type as 'chair' and it is, therefore, defined as an 'improper not chair,' that is it should not be considered as relevant in defining the boundary between the 'chair' and 'not chair' categories.

5.2.5 Prototype abstraction versus feature differentiation strategies

There are problems with Rosch's theory, however, in particular with the notion of class inclusion being based on family resemblance or number of shared attributes. Reed (1972) asked students to classify line drawings of simplified faces and found that the predominant strategy used by the students was to match examples to prototypes. Some subjects, however, matched individual features such as the length of nose or the set of the eyes, and then matched on the similarity of these individual features. Similar results were found by Hyman and Frost (1974) and by Neumann (1977).

In the latter case, Neumann was able to manipulate whether or not a prototype abstraction or feature differentiation strategy would be employed. Once more using simplified faces as the stimuli, he found that if subjects were exposed to example faces composed of a range of extreme and non-extreme features, then they averaged the data, that is they built and used prototypes. If, however, only extreme cases were presented, or the facial dimensions were made explicit to subjects, then they were more likely to recognise extreme examples in the post-presentation situation, indicating that they were differentiating on variations in individual features. In a second experiment, using geometric figures as the stimuli, Neumann (1977) found no evidence of prototype generation, rather the subjects appeared to focus on extreme features.

Homa (1984) argues that laboratory experiments with single categories, such as those described above, are limited in their importance because they fail to take into account the relationship of the experimental category to other categories. Like Bateson, he believes that categorical information can not be acquired in a vacuum without recourse to other categories. For example, he suggests that a child cannot adequately learn about 'dogs' without also learning about related categories such as 'cats.' He, therefore, argues that experiments in the Neumann mould can provide useful information on similarity processing, but the results are not extendable to multiple category situations.

Research by Labov (1973) throws further light on the prototype abstraction versus feature differentiation debate. He investigated people's concept of 'cup' by presenting subjects with line drawings of a range of typical and atypical cups, for example one-handled, two-handled and no-handled cups, in a variety of contexts. The context was either neutral, that is a picture of just a cup, or suggestive of function, a cup filled with coffee, flowers or mashed potatoes. Context had no influence on the classification of prototypic cups or, on cups which were strongly atypical, but examples which were considered at some distance from the prototype but not borderline cases were context bound. If they contained coffee they were defined as cups but not when they contained flowers. This effect of context brings into question assūmptions about class membership being governed by a static set of defining features.

These experiments show that the classificatory strategy employed by individuals is governed by the nature of the problem to hand, and although the prototype abstraction model accounts for many instances of categorisation, it is not the sole strategy available. The strategy employed will depend on the nature of the stimuli and on the nature of the category. If the category is deterministic, with clearly defined boundaries, then rule-based or exemplar strategies are generally employed. If the category is probabalistic then prototypical strategies come to the fore (Homa, 1984).

Bransford (1979) argues that it is conceptual flexibility that underlies the ability to choose sets of defining features dependent on context and purpose, but that in choosing those features we are not implying that they are the inherently defining attributes of the concept. While it is important that we are able to limit our flexibility of definition, otherwise communication could not take place between individuals, the ability to be contextually flexible is important because new ways of defining concepts can lead to new insights about those concepts.

5.3 Organisational structures and asking questions.

The emphasis in the research which will be discussed here, is on how the individual comes to understand, search for and retrieve the answers to questions, an approach which defines thinking as a search of semantic memory. Within education, current curriculum changes, such as those promoted in the Nuffield Science Curriculum, necessarily emphasis the ability to test hypotheses through a logical search of alternatives. This ability to hypothesise and to ask good questions, in order to select between alternatives, is partly dependent on the child's ability to pick out relevant features of objects and to group them. Yet, as Mosher and Hornsby (1966) point out, we should recognise that what we ask and how we use the answers both depend on how we organise knowledge.

Organising the vast amount of material impinging upon us is a necessary precursor to making decisions and taking actions. In much of the literature on categorisation there appears to be little differentiation between grouping objects or concepts, and developing a coherent organisational structure of the material, and the ability or willingness to use those structures. Mosher and Hornsby (1966) have shown, however, that the achievement of grouping skills, including the ability to construct superordinate category labels, does not necessarily mean that those structures will be used in problem solving.

They investigated the development of children's cognitive growth, revealed by the children's approach to a simple information sorting puzzle. The children, in the age range six to eleven years, were to identify the one card that the experimenter had chosen and was thinking of, from a set of forty-two picture cards laid face upwards on a table. The children could elicit information from the experimenter to help them in the task by asking any number of questions. However, the questions were required to be such that a simple yes/no answer was always appropriate. The children employed two main types of strategies to solve the problem. The 'hypothesis scanning' strategy involved questions each of which tested a self-sufficient, specific hypothesis, which bore no necessary relationship to the previous questions. The 'constraint seeking' strategy, on the other hand, built question upon question, each systematically reducing the number of possible answers to the problem.

They found that six year olds operated an exclusively 'hypothesis scanning' strategy, but by eight years of age constraint questions were an important part of the child's approach, and this shift in strategy continued into the eleven year old group. They argued that the lack of constraint questions for young children was due to a lack of superordinate-equivalence categories, a necessary prerequisite for 'constraint seeking' strategies. The disparity in the degree to which the contraining strategy was used by eight and eleven year olds, was a function of a growing appreciation with age of the fact that general questions were the key to resolving the problems. They were aware that some children with the ability to develop superordinate groups did not use this skill in their tests and they suggested that these children had not mastered the skill of hierarchical organisation, the underpinning structure of the constraint seeking strategy.

This division between being able to identify superordinate categories and being comfortable with hierarchical structures can be inferred from the work of Giboin and Michard (1984). In a study of the acquisition of programming skills, they found that the use of hierarchical structures was initially quite difficult for eleven to thirteen year old children, but with directed practice the use of these structures increased. The evidence, therefore, suggests that efficient problem solving will depend first on developing good classificatory skills and then on a growing appreciation of the organisational structure of information.

Morton, Hammersley and Bekerian (1985) have also addressed the question of how we retrieve answers to specific questions which provide the knowledge used in the course of any cognitive operation, in order to make sense of our environment and to guide our actions. They argue that simple everyday phenomena, such as the inability to retrieve a name while, at the same time, being able to recall other information about a person, cannot be explained by either the associative network nor the schema model of memory. In the latter case, all information related to a person should be subsumed under the schema title or name and, without access to the name, all other information should be irretrievable, but in their example this is clearly not so. In the associative network theory, concepts are represented as nodes with links defined by the nature of relationships between those nodes. Morton <u>et al</u>. have suggested that this theory requires some sort of blocking of the pathways linking the name node and other nodes referring to that person, in order to explain the partial retrieval of information. However, such a blockage would violate the concept of content addressability, that is, if one node is available all other associated nodes will also be available, an underlying assumption of the theory.

The headed-record model, they argue, can explain a number of retrieval problems. Loftus, Miller and Burns (1978) have offered convincing evidence that memories for events are subsequently modified by post-event information. In one experiment they showed a slide sequence of a motor accident. Subjects saw a slide depicting a STOP sign but were later told in a questionnaire that they had seen a YIELD sign. As many as 80% of the subjects fed this false information reported seeing a YIELD sign in a subsequent test. Morton <u>et al</u>. argue that far from the memory being altered by the post test questionnaire, the apparent failure of the subjects to report the correct information is best explained by the absence of critical information at test.

The original slide sequence is stored in memory in a headed record, while a second record is constructed to store the new but inconsistent information from the questionnaire. Both records exist in memory but only one can be retrieved at a time. As retrieval operates on a 'last-in first-out' principle, the slide sequence record heading would need to be discriminable from that of the questionnaire heading and the information in that key heading would need to be present when the subjects were tested, in order for that record to take precidence over the later record. They argue that the randomising of the slide sequence in the test violated one of the key facts stored in the slide sequence record heading: the sequential theme-related information of the accident. Accordingly, the heading for the more recent record, that constructed from the questionnaire, would be matched and the inconsistent information would form the basis of subjects answers. Bekerian and Bowers (1983) provided support for this interpretation of the data. They repeated the Loftus et al. experiment but in the final critical test they had two conditions, a randomised and a non-randomised slide presentation. In the first condition they also found that inconsistent information was retrieved by subjects, but no misleading effects were found when the original sequence was followed during the test. This study suggests that if we do not appreciate the organisational structure of our information, then we will construct inappropriate queries that lead to either incorrect and misleading answers or, possibly, to no outcomes at all.

Although the controversy over which organisational structure best models the human memory has yet to be resolved, there is sufficient empirical evidence to show that the development of classificatory skills are important to both the storage and retrieval of information. Secondly there appears to be a consensus of opinion that the attainment of superordinate-equivalence is a critical step in the individual's ability to solve more advanced cognitive problems. Categories may be constructed by reference to both prototypical cases and to the process of feature matching, the choice of classificatory strategy being governed by environmental cues, familiarity and the nature of the material to be grouped. The attainment of grouping skills, however, does not necessarily indicate that the individual, particularly the child, has come to appreciate fully the usefulness, for problem solving, of the structure inherent in their category organisation. Finally there is evidence that the type of organisation will influence the nature of the questions that we can ask and indeed the answers we will receive. This is a common sense conclusion. It is difficult to find a library book without at least a rudimentary knowledge of the classification system employed by the librarian. Equally it is virtually impossible to find the owner of a known telephone number from a conventional teléphone directory.

5.4 Education and Information-handling Skills

As has been discussed in Chapter 1, there is now a powerful lobby within the educational system arguing for a process rather than a fact orientated curriculum in U.K. This focus on information manipulation can be explained in a number of ways. Summerville (1983) points out that modern methods of communication have, and are, resulting in an exponential increase in the quantity of data impinging upon the individual. It, therefore, becomes imperative that each person develops information-handling skills in order to make sense of the world. These skills, as has been shown, are underpinned by an explicit understanding of the organisational structure of categories. Indeed an understanding of such concepts appears to be important for many aspects of intellectual functioning.

The problem is not seen simply as one of individual survival, however. The nation's future is also at stake. It is has been argued that our future economic success depends on the degree to which children are taught to be sufficiently flexible and adaptable in their thinking and actions to handle the pace of change brought about by information technology. As Gagné (1970) has stated, the most important things learned in schools are intellectual skills not verbalised knowledge. Longworth (1981) paints a very gloomy picture, however. He considers that what today's children learn at school, at best, has a useful life of half a generation, while at worst it is obsolete as it is taught!

Labbett (1985), building on Gagné's (1970) assertion that learning in schools is largely information processing, argues that teachers and pupils are already information-makers and information- handlers,' and that all curricula are information-handling curricula. To a degree she is right, for we must all handle information to survive and, as Olver and Hornsby (1966) have pointed out, even very young children operate processes of discrimination. The evidence from both Mosher and Hornsby (1966) and Giboin and Michard (1984) suggests that knowing is not enough, however. The relevance of the skill to any problem has also to be understood before it is used to any effect.

There is also strong evidence that the emphasis in classrooms is on factual knowledge combined with very limited structural organisation of information rather than on information-processing skills. Becker (1982) has shown that in the area of computer-based learning (CBL) drill-and-practice programs predominate. This emphasis on knowing facts rather than applying cognitive skills was a worry highlighted in the Cockcroft Report (1982) on mathematical education. An evaluation of the use of mathematical software in schools (Ridgeway, Benzie, Burkhardt, Coupland, Field, Fraser and Phillips, 1984) also showed that, even with good support material, it is difficult to shift the classroom focus towards higher cognitive skills. They observed teachers and pupils using non-drill-and-practice programs, which developed important skills of mathematics identified as neglected in most classrooms by the Cockroft report. They found that these programs led to an increase in discussions of hypotheses and in problem solving, but Cockcroft's missing 'investigational work' was not facilitated even though software aimed at stimulating such work was available to the teachers. They concluded that such packages were not used because teachers could find no way of fitting them into the existing curriculum.

Curricula which fossilise information into facts to be known, rather than into material to be manipulated and thought about, may be nearer the truth for many classrooms than are those described in Labbett's (1985) hopeful comments. Nevertheless there is an awareness of the need to change the emphasis in education, although this may prove difficult as old ways are tenacious.

5.5 The Computer and Information-handling Skills.

The argument presented here is that we must not expect children to fine-tune their information-handling skills unless they are presented with opportunities which exploit those skills. As the advent of information technology has, in part, forced us to revalue the direction of education, it seems most appropriate that we should use the new technologies to encourage those cognitive skills needed to process the growing tide of information. An important question to be asked here is is whether one particular type of instruction is more conducive to the development of classificatory skills and the processes involved in information-handling than another.

The premise on which much of the following research section is built, is that such skills are actively encouraged by the ready availability of data storage and retrieval systems, of which there are now a number specifically designed for educational microcomputer systems. Rushby (1979), in his classification of educational software, categorised data-base programs as 'Conjectural', that is they encouraged thought rather than mere assimilation, and emphasised the manipulation and analysis of data, the use of abstractions and the testing of ideas and hypotheses. This definition strongly suggests that information retrieval packages will have an impact on classificatory skills, and many teachers are using such programs with this educational goal specifically in mind (Chandler, 1984; Ross, 1984; Stewart, 1984). Additionally, it is suggested that in quizzing a data-base even young children can begin to ask 'good' questions and be introduced to a hypothesis-testing-strategy approach to learning. What constitutes a 'good' question will be discussed at some length in Chapters 7 and 8.

There are, however, other methods of teaching than the investigative approach outlined above. Although the use of the computer as a tutor is often frowned upon in education at the lower age ranges, practice/tutor programs are widely used. In higher education they are both widely used and have a far more respectable image (Bork, 1983; Kearsley and Seidel, 1985). Such programs may also have a role to play in developing classificatory skills, for they can make explicit the defining features and the organisational structures of any classification.

Finally what will be the effect of exposing children to software which encourages them to find new classifications for seemingly disparate concepts, and encourages novel uses of objects to resolve design problems. Such programs lack the explicit organisational structures of knowledge-based systems and tutoring programs but they do encourage children to think about the nature of any object and the many dimensions along which grouping can take place.

CHAPTER 6

DATA ORGANISATION AND RETRIEVAL BY YOUNG CHILDREN

6.1 Introduction

The increasing use of information-handling packages in recent decades stimulated research investigations into how people organise data (Durding, Becker and Gould, 1977; Brosey and Shneiderman, 1978). The underlying aim of such research is to facilitate the use of computer information packages by matching, where possible, software structures to the organisational structures most readily available to humans. If matches are not possible, the software designer, and the potential users, at least, need to be made aware of the potential problems in the use of any program. Although the applied aims of the research might appear new, the theoretical and methodical approaches are firmly based in cognitive psychology, and, in particular, in research on the structure of memory, an approach which views problem solving as a search of ones meaningful memory (e.g., Underwood, 1976; Anderson, 1980; Mayer, 1983). The computer metaphor arising out of machine-based information systems is now, in turn, influencing the formulation of models of human memory (cf. Morton, Hammersley, and Bekerian, 1985).

The assumptions of such research on cognitive ergonomics is that memory is organised in such a way that new information can be easily entered and can be, at a later date, efficiently retrieved from the memory store. The aim is to discover the nature of the specific organisational schema on which these high-level cognitive activities are based. Durding et al. (1977) have argued that there is substantial experimental support for a number of organisational models, including lists, hierarchies and networks, but that no one model fully explains how memory is functionally organised, because the type of organisation used is task-dependent.

6.1.1 Previous Research

The collective findings from the investigations in this area suggest, therefore, that a number of organisational structures are readily available for people's use. We are not resticted to using one data organisation because we have the flexibility to adapt our cognitive processes to a variety of information structures. Durding et al. confirmed that adults (undergraduates), when faced with word sets exhibiting a range of pre-defined organisational structures, were capable of recognising and making explicit those structures. The task presented subjects with word sets, 15 - 20 words long, and the subjects were asked to organise the word sets in a way which maintained and, made explicit, the semantic relationships among the words. Each word set had a natural organisation such as a tree, network, list or table. There was, however, a ranking of ease of use in the order: lists, hierarchies, networks and tables. The latter was the only organisational type with which subjects achieved less than a fifty percent success rate. This order was not maintained when subjects were primed as to the appropriate organisation to use, by the inclusion of a skeletal diagram accompanying each word set. Lists and hierarchies were still the easiest to recognise, but they were now followed closely by tables. The provision of an overt structure did little to facilitate the recognition of networks. A small number of the subjects tested in each condition applied the same structure, that is a list structure, to all data regardless of the pre-defined organisational structure, but the overall findings were that adults were aware of, and were capable of, constructing a variety of organisational structures.

Rather than asking their subjects to construct organisational structures, Brosey and

Shneiderman (1978) asked them to access information from databases, with either a tree (hierarchical) structure or a tabular structure. The tree structure proved to be an easier retrieval format, and it was also easier to commit to memory and to reproduce, than the tabular structure.

The two sets of experiments together suggest that , after lists, hierarchies or trees present data in the most readily accessable form for adults, but that other organisational structures may be used with some measure of success, if the subject is made aware of the relevance of that structure to the task in hand.

The conclusions to be drawn from this research are that the type of data structure available will influence the efficiency with which adults both input and output material from a data-base. As the use of educational information-handling packages grows it becomes pertinent to question whether these findings are applicable to younger subjects and, if so, what are the implications for the use of information-handling packages in school? The use of such packages is to be welcomed, not only because they will familiarise children with the concepts underlying a new information technology, but also because they facilitate cognitive development (Underwood and Underwood, 1987). The most common knowledge-based systems for U.K. schools use either a hierarchical (e.g., SEEK, TREE OF KNOWLEDGE) or tabular (e.g., FACTFILE, INFORM, QUEST, GRASS) structure. SEEK and TREE OF KNOWLEDGE both use a binary tree structure, in which information is sorted or classified linearly through a series of non-probabalistic yes/no answers. FACTFILE and INFORM both operate a matrix structure of fields and records.

A network structure has not commonly been chosen as the underpinning organisational structure for educational data-bases. The results of Durding et al. (1977) and Brosey and Shneiderman (1978) would suggest that this is a wise exclusion. Tables, and particularly hierarchies, are more likely to achieve that congruency between the existing organisation in the user's mind for a particular task, and the representation of information by the computer to the user, which should facilitate the successful manipulation of the data-base.

The following investigations were designed to test the significance of the research of Durding et al. (1977) and Brosey and Shneiderman (1978), which had used an adult subject pool, to the use of data-bases by children in the age-range nine to eleven years. This age-range was selected for two reasons. Pragmatically, children in the upper junior school are a target population for those trying to encourage the use of information-handling packages in the schools, because such packages fit so well into the topic-work approach that forms a core element in U.K. classrooms at this age. Secondly, work, such as that of Olver and Hornsby (1966), suggests that by nine years of age many children are capable of developing superordinate categories, a necessary precursor for defining complex organisational structures, although they add the rider that the categories so formed are not always particularly appropriate.

The key questions in this research were:

1. Have young children a range of organisational structures readily available for use?

2. Do young children use different organisational structures to adults?

3. While children might be expected to have lower overall organisational proficiency than adults, is the pattern of that proficiency qualitatively the same; that is, do they produce the same rank ordering of ease of use for organisational structures as was found for adults?

6.2 Experiment 1: Organising Data 1

6.2.1 Introduction

The aim of this first experiment was to investigate the types of organisational structures children would employ when asked to sort a set of objects depicted on cards. This experiment was a precursor to Experiments 2 and 3, which followed closely the work of Durding et al. There was no one pre-defined organisation to the material. It was perfectly possible to sort the cards into lists, hierarchies and tables, although not into networks. The picture cards provided a less abstract stimulus set than the word sets in Durding's experiments. They could be physical manipulated and did not engage the child in a reading task. Together these characteristics reduced the task difficulty and allowed the child to concentrate on producing a structure to make overt the relationships between the objects. Unlike the investigations of Durding et al., which assessed children's abilities to recognise and reconstruct pre-defined organisational structures, this study monitored the organisations children chose to use when a number of structures were possible. The children were asked to organise the same stimuli in two ways to give some measure of the types of organisation available to each child. It was also hoped that in encouraging a second sort of the cards it might be possible to stimulate the children to use more complex organisational structures such as hierarchies and tables.

6.2.2 Method

Subjects

Subjects were 50 school children aged between 9 and 11 years, all members of either a third or a fourth year class of a junior school. Subjects were tested for their reading ability (McLeod, 1970), and for their non-verbal spatial ability (Raven, 1956).

Materials

The materials consisted of twenty-four cards with a simple line drawing in black ink on white card. The drawings differed on two dimensions, object type and number of objects. The objects were equally divided on level of concreteness (Heidbreder, 1946 and 1947) into concrete objects, toys, and abstract objects, two-dimensional geometric shapes. Six examples of each category were presented: cards depicting toys included footballs, teddy bears, rattles, dolls, spinning tops and alphabet blocks. At a further level of abstraction, each object was represented singularly and as a pair of identical objects.

Procedure

All subjects were tested individually. The experimenter randomly placed the twenty-four cards face upwards on the table. Subjects identified verbally the object depicted on each card. A precise name was not required from the child as long as the object stayed within its pre-defined category. Once the subjects had identified each card they were told that the objects on the cards were related in some way and that their task was to discover what those relationships were and to re-arrange the cards to make explicit those relationships to the experimenter. The children were actively encouraged to articulate the reasons for the organisations they constructed. Once they had completed the task they were asked if they could think of a second way to organise the material. Note was taken of both the working comments and final solutions from each subject. There was no time constraint to this task which took between five and thirty-five minutes to complete.

6.2.3 Results

Scoring

Subjects' organisations were classified initially on two criteria: the number of criteria employed in sorting the cards, and the use of superordinate category labels or subordinate category labels.

The four organisations produced using these criteria were:

Name	Description	Example
List 1	Simple division on one criterion using a superordinate category label.	toy/not toy single/not single
List 2	Simple division on one criterion using a subordinate category label.	types of shapes
Table	Division on more than one criterion (superordinate) applied across all the objects to form a matrix or table.	toy/not toy sub-divided into single/ not single
Hierarchy	Division on more than one criterion applied linearly to form a hierarchical structure. Each main division sub-divided on category specific (subordinate) criteria.	toy/boys/babies - shapes/round/ angular

These four categories failed to handle all of the data, however. Two additional categories were used for scoring purposes. A number of subjects organised the objects into pairs. Although such an organisation could be viewed as a special case of List 2, where grouping was by subordinate features only, it was felt that pairings were sufficiently different to be classified separately and they were termed primitive lists. These primitive lists are equivalent to the multiple groupings, complex structures in which the stimuli are formed into a segmented list with no bridging of the gap between the various groups so formed (Olver and Hornsby, 1966). List 2 organisations, on the other hand, were formed by the use of a subordinate criterion across all or most of the groups. It was this application of any one criterion across groups which differentiated the List 2 and primitive list structures.

A few of the organisational structures were idiosyncratic and termed 'others.' For example, one child formed four groupings with the titles: "I like these pictures;" "I play with baby with them;" "These are blocks;" and, "Those are the others." This child , in defining her organisational structure, covered four of the five main modes of equivalence as defined by Olver and Hornsby; these were respectivly affective, functional extrinsic, perceptual intrinsic, and fiat equivalence.

The subjects' organisational structures were, therefore, classified into six categories primitive lists, lists using superordinate criteria, lists using subordinate criteria, tables, hierarchies and others. The subjects each contributed two scores, that is, they were asked complete two sorts of the cards.

Analysis

Table 6.1 shows the percentage frequency of each type of organisation produced by the young subjects.

Table 6.1

Percentage Frequency of Each Type of Subject Organisation. (N = 50)

Subject organisation	Primitive List	List 1	List 2	Table	Hierarchy	Other
% frequency	39	21	8	5	23	4

All figures are rounded to the nearest whole number.

The results (Table 6.1) show that the young subjects were quite capable of imposing a recognisable order on the stimuli. Only 4% of the organisational structures were idiosyncratic (others) and were accounted for by three children. One subject produced two idiosyncratic structures, but the other two subjects produced consistent classifications for their first structuring but lost this consistency when asked to reorganise the material. The most prevalent organisation was the primitive list, an organisational type not used by the adults in the Durding et al. studies. This figure is rather high compared to that of Olver and Hornsby, who found that on their picture organisation task, eight year olds used pairings 36% of the time and this had dropped to 25% for eleven year olds. Primitive lists are defined using subordinate category features. The children defined just under half of their structures using these lower level characteristics only (primitive lists 39%, list 2, 8%).

The use of superordinate category labels is essential to produce useful classifications, however. In this study 70% of the children used superordinate characteristics to define one or more of their organisations, a figure very much in line with the findings of Olver and Hornsby. Fifteen children (30%) failed to identify either of the superordinate criteria: object type or number. Of the organisations using superordinate criteria, lists (List 1, 21%) and hierarchies (23%) were equally favoured. In organising the stimuli into either of these structures subjects needed to use only one dimension at a time. For the hierarchies the children divided the stimuli using either the 'toy/ not toy' or 'single/ not single' dimension. They then went on to work down each branch of the hierarchy using subordinate category features. Tables (5%), which required the subjects to operate on both superordinate dimensions, proved extremely difficult for these young subjects.

Comparison of the two organisational structures produced by each child showed that 64% of the sample employed two different structural organisations, and for these thirty-two children, 66% of the second organisations were more complex than on the first trial, using superordinate categories and/or consistently using more than one criterion. All but one of the children who used a simpler organisation as their second offering presented a primitive list, and this included children who had devised tables or hierarchies on the first trial. It would appear that once having established a satisfactory organisational structure it was very difficult for these children to re-organise the material. One child, however, did succeed in producing first a table (object type and number) and then a hierarchy (object type and shape)using different criteria consistently across her organisations.

6.2.4 Discussion

The results of this experiment suggest that, while there was a wide range of organisational structures which could have been used to make sense of the pictorial stimuli, these young subjects most frequently used lists, of one type or another, as their preferred organisational structure. The primitive list, or pairing, was the most prevalent of all the data structures.

Newport and Bellugi (1978), in their analysis of American Sign Language, found that single signs were used for base level terms for natural categories(Rosch, Mervis, Johnson, and Boyes-Braem, 1976) such as apple, but superordinate and subordinate categories were represented by compound signs, suggesting that when a restricted vocabulary was available, humans prefered to operate at the base level. In this study the most prevalent organisation generated by the children, the primitive list, was devised when children concentrated on toy or shape names (teddy bear, circle) which are basic level terms (Rosch et al.).

Many of the children proved capable of employing more than one type of organisation to make sense of the stimuli, however, and their second restructuring of the material often lead to a more detailed or complex organisation. Of these organisations, hierarchies (23%) were constructed with greater frequency than tables (5%), which were offered by very few subjects.

The results from these children showed a superficial similarity to the pattern of performance of adults (Durding et al.), where lists, hierarchies and tables were used with decreasing proficiency. The use of list stuctures was far more important for the young subjects, however, and a low level organisational structure, the primitive list, featured prominently in their solutions. Hierarchies ususally emerged on the second sort when the children were pressed to reorganise the material.

6.3 Experiment 2: Organising Data 2

6.3.1 Introduction

The second experiment, also designed to determine the organisational structures available to young children (9 - 11 years of age), followed closely the experimental method of Durding et al. (1977). The objective of the experiment was to investigate the types of organisational structures young children would employ when asked to sort word sets. The main question was whether the choice of data organisation employed would be determined by the pre-defined semantic relationships within each word set, or whether subjects would operate one predominant structure regardless of those pre-defined semantic relationships.

In order to answer this question subjects were asked to organise word sets which, unknown to them, had the following pre-defined structures; lists, hierarchies, networks and tables. There were a number of reasons for choosing these particular data structures. In the first place hierarchies and tables form the underlying structure to a number of common educational computer information-handling programs, such as binary trees (e.g. SEEK) and data-bases (e.g. FACTFILE and INFORM). In more advanced or commercial data-bases, networks are also widely used as the underpinning structure (Shneiderman, 1980). Secondly, the types of stimuli presented matched those in Durding's experiment. Hence, comparisons were possible between the organisational structures available to adults and to children. Durding et al. argued that these were relevant structures to investigate because of their frequency of use in day-to-day events; because hierarchies and networks have been considered as possible organisations for information in human memory (cf. Collins and Quillian, 1969, 1972; Anderson and Bower, 1973); and because these structures were used by Wortman (1966) and Schwartz (1971) in their studies on problem solving.

6.3.2 Method

Subjects

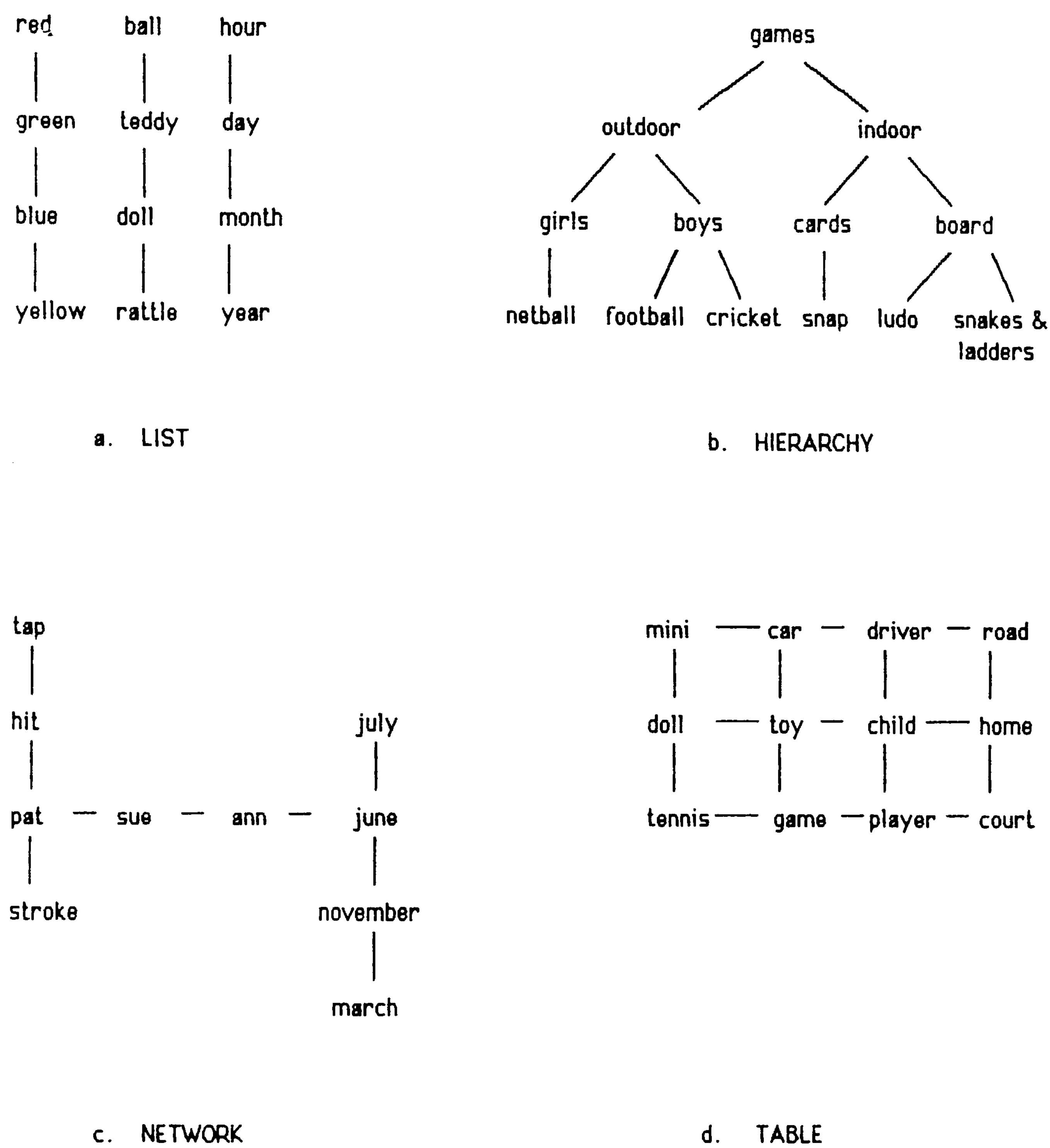
Subjects were 38 school children aged between 9 and 11 years, all members of either a third or a fourth year class of a junior school. Subjects were tested for their reading ability (McLeod, 1970), and for their non-verbal spatial ability (Raven, 1956). These subjects did not participate in Experiment 1.

Materials

The materials presented to each subject consisted of five word sets of 10 or 12 words each. The words within each set were selected to conform to one of the selected pre-defined organisational structures; lists, hierarchies, simple tree networks and tables, and in addition, a group of random words, designed to have no apparent semantic organisation, were used as a control condition. An example of each structure is found in Figure 6.1. Two separate, but similar, sets of material were developed. There were, therefore, two word sets corresponding to each of the four chosen organisational structures and there were two sets of twelve 'random' words. This produced five types of word sets for which there was two instances of each.

Figure 6.1

Examples of word sets used for each of the pre-defined organisations in experiments 2 and 3.



As this experiment was conducted with much younger subjects than those used by Durding et al. (1977), the number and type of word sets presented to the subjects were severely limited. Two word sets were organised as lists consisting of high frequency examples of three semantic categories taken from Rosch (1975). No category names were included and these word sets were similar to Durding's lists. The two hierarchical structures consisted of words relating to common flowers and to children's games. Each hierarchy had four levels. Networks, as defined by Durding, contain; "words with multiple meaning relationships to other words in the set." Thus JUNE, in Figure 6.1c, is related to NOVEMBER and to SUE. Figure 6.1c does not constitute a full network as there is no cycle present. This simple network was used because of the immaturity of the subjects. Two sets of words with a network organisation were produced and this was also the case for tables. Each column of the table consisted of words chosen from one semantic category while each row contained words which were semantically related across semantic categories. Both of the word sets were organised as complete tables.

Each subject received a booklet containing five word sets, each printed in a single column on a separate sheet, and representing each of the five types of experimental stimuli. The presentation order of the stimuli was randomised for each subject.

Procedure

Subjects were tested in their two class groups. The two groups of five word sets, which comprised the booklets, were given out alternatively to the children in the class. Thus neighbouring children within a class worked on different word sets.

The subjects were told that the words on each page were related in meaning and that their task was to discover the relationships among the words. Then they were to rewrite the words in such a way as to make the relationships they had discovered apparent to the experimenter. They were told that the words were not intended to make up a sentence and that the printed order of the words on the sheet was unimportant. There was no attempt to prime subjects as to the possible organisational structures they might use, by the provision of exemplar structures, but a brief question session was allowed to make sure the children understood the task at hand.

Emphasis was placed upon the lack of any time constraint. Time-on-task was not taken as a measure of performance because it would penalise those children with poorly developed writing skills. Subjects were told that they could have as many tries as they wanted before coming to their final decision but after they had turned over to the next example they were not to go back. The subjects worked through the five examples at their own pace, which took from 30 to 45 minutes.

6.3.3 Results

Two scoring techniques were developed. The first scoring technique was a simple measure of the type of organisation used by each subject and matched that used by Durding et al. The second scoring technique measured the degree to which subjects recognised relationships among words but did not require the subject to demonstrate an overt recognition of the pre-defined organisational structure.

Simple scoring technique and analysis. This initial method of scoring was a measure of organisational structure alone and took no account of the accuracy or semantic sufficiency of the subjects' work. The results of this analysis are presented in Table 6.2.

The subjects' organisations were classified into the four pre-defined organisational structures to give the contrasts shown in Table 6.2, but it was apparent that these young subjects frequently used organisational structures other than those defined by Durding et al. Several subjects actually identified the random stimuli as random, commenting that they could see no pattern in the meaning of the words. Others simply reorganised the word set into alphabetical order or added synonyms to each of the stimuli words. More important, however, a number of subjects organised the word sets into pairings. This organisational structure can be thought of as a primitive list. The subjects organisational structures were, therefore, classified into seven categories; lists, hierarchies, networks, tables, defined-random, primitive lists and 'others.' 'Others' included the alphabetical and synonym structures. Whereas Durding's adult subjects occasionally left a word set without any visible attempt at organising the material, the children in this experiment either attempted some sort of organisation or stated that the words had no relationships in every trial. These categories, therefore, described 100% of the subjects' organisations. There was no ambiguity in the subjects' structures and it proved quite easy to place each one into one of the seven categories.

Table 6.2

Percentage frequency of each type of subject organisation for each type of pre-defined organisation in Experiment 2. (Simple scoring technique. N = 38)

	Pre-defined Organisation					
Subject Organisation	List %	Hierarchy %	Network %	Table %	Random %	Total %
Lists	**82**	66	61	76	26	62
Hierarchy	0	**8**	0	0	0	2
Network	0	3	**21**	3	5	6
Table	0	0	0	**0**	0	0
Defined as Random	0	0	0	0	**16**	3
Primitive List	8	18	11	13	47	20
Other	11	5	8	8	5	7

Figures in bold indicate the % match between the pre-organisational structure and the subjects' organisation of words. All % are rounded to the nearest whole number.

Table 6.2 shows the percentage frequency of each type of subject organisation for each type of pre-defined structure. On average, only 25% of the word sets were organised in a way consistent with their pre-defined structures. Further, it can clearly be seen that the young children have a strong preference for list organisation; 62% of all word sets were organised into list structures. Of word sets with a pre-defined list structure, 82% were organised into lists. Subjects had little success with the other three pre-defined structures. Hierarchies (8%) and tables (0%), proved very difficult for these young subjects, and were rarely organised into their pre-defined structures. Indeed the children were more likely to recognise the lack of structure in the random word sets (16%) than to recognise the hierarchical or tabular nature of the data.

Complex scoring technique and analysis A second more detailed scoring technique was also used. Here subjects organisations were matched to the pre-defined structure of the experimenter. The recognition of the semantic relationships within the word sets was now important. Each subject's score was incremented if they had maintained the relative position of the word within the experimenters organisation, but an exact pattern match was not necessary.

Each list word had only one relevant relationship - its placement into a group - but there was no ordering within the group. Each hierarchy and table word had two relevant relationships. For hierarchies, any one word was related to words both above and below it in the hierarchy. For tables, relationships were defined within each row and column. A network word had one relevant relationship, its place within a group but not the order within the group, unless the word lay on a node. In that case the word would have two relationships.

Thus for a list, a score of 12 points could be achieved by placing the twelve words into the three pre-defined groups. Although many children achieved a full score others recognised only two groups or failed to find the fourth member of one or more groups. For networks, where ten words completed a set, one point was awarded for correctly designating each member of the group, as in with the lists, but words with dual meanings could acquire two points if appropriately placed, that is if the child recognised its membership of both groups. For the hierarchies, children were required to recognise the subordinate and superordinate member associated with any word, achieving half a point for each. For tables, recognition of the class type (table column) and semantic relative (table row) each received half a point. Altogether a score of 12 points could be gained for each of the pre-defined organisational structures.

This second, detailed scoring technique examined the degree to which the subjects matched their organisational structures to the four pre-defined organisational structures. The control condition, random words, did not feature in this analysis as it was not possible to define a correct response. A one-way, within-subjects analysis of variance showed that the young subjects responded differently to the different data organisations ($F=50.2$; $df=3,108$; $p<0.0001$); that is, they were not able to match the pre-defined structure with equal facility in all cases. This confirms the data from the first simple analysis shown in Table 6.2.

Table 6.3

Mean percentage score for the degree to which subject organisation matched the experimenter's pre-defined structure. (Complex scoring technique - maximum achievable score 12. N = 38)

Mean Degree of Organisational Match	Pre-defined Organisation			
	List	Network	Hierarchy	Table
mean% score	74.3	51.4	29.9	27.8

Performance contrasts in Expt.2 Conditions joined by a common line did not differ from each other, according to Tukey's HSD test.

Mean percentage scores representing the degree of organisational match achieved between the subjects and the experimenter, for each of the four pre-defined organisational structures, are shown in Table 6.3. The Table also shows the results of the paired comparisons using Tukey's HSD test. Hierarchies and tables did not differ from each other, but they did differ from both lists and networks which, in turn, differed from each other.

6.3.4 Discussion

This investigation sought to answer several questions. The first question was whether young children (9 - 11 years of age) can organise information according to a pre-defined structure. The corollary of this question is whether young children use a single organisational structure despite the internal organisation inherent in that information. The answers to these questions allow a comparison between the organisational structures available to, and preferred by, adults (see Durding et al., 1977) and young children.

A comparison of these data with the results from Durding et al. (simple scoring technique only - Table 6.2) revealed not only a quantitative but also a qualitative difference in responses. These young subjects were less successful at identifying the pre-defined structure (25% success rate) than the adults (59%) of Durding et al. These figures were not totally comparable as Durding's results did not include correct responses for the control case, random word sets, but did include a finer gradation of lists and tables into categorised and non-categorised. Although lists were recognised almost as easily by the children (82%) as the adults (96%), there was a very poor response to other types of organisation. Hierarchies caused particular difficulties for the younger subjects (8%) as compared to the adults who found this type of organisation quite easy to handle (79% correct responses to hierarchical organisations) who found this type of organisation quite easy to handle. Networks proved relatively less difficult for the younger subjects (21%) than hierarchies, a reversal of the Durding et al. results. Tables were poorly handled by both groups, however.

Consistent with Durding's findings, subjects largely reverted to list structures if they could not recognise the semantic structures in the data, or if they were having trouble with a more constraining structure, that is a structure which requires the subject to recognise more than one semantic relationship. For example the semantic relationship between rows (semantic relative) in a table might be recognised while the relationship between columns (class type) might not. Of the non-random word sets which were organised differently from their pre-defined structures 69% were classified as lists, 0% as hierarchies, 2% as networks, 0% as tables, 19% as primitive lists with 13% of other types of erroneous organisations.

The control case, random word sets, was the only 'structure' for which lists (26%) were not the dominant organisation employed, here young subjects reverted to primitive lists or pairings (47%). Hierachies, networks, tables and other types of organisation were not seen as viable organisational structures for the random word sets. These young subjects actively treated the random word sets differently from the pre-defined structures word sets. This fact, coupled with the success, albeit limited, of young subjects in actually specifying a lack of relationship within the random words, strongly suggests that they saw the experimental and control word sets as different and, although they could not always tease out the relationships in the pre-defined word sets, they were aware that a relationship existed. No word set in the four experimental conditions was defined as random by these young subjects.

This is not the case for the adults in the study by Durding <u>et al</u>. They found that the pattern of error scores (that is words organised incongruently to the pre-defined structure) for the non-random word sets were very similar to that for the control condition, random words. In both cases list structures were the most frequent type of organisation employed (75% for non-random; 69% for random word sets) and all word sets in both the experimental and control condition were organised into one of the pre-defined organisational structures. No adult argued that the control condition was indeed random.

The failure of young subjects to use a range of organisational structures may have been due to the lack of familiarity with the more constraining structures; or the limited cognitive ability of many subjects to work with more than one dimension at a time, as would be required by the tabular structures in particular; or the mode of presentation of the stimuli. In the latter case list structures may have been induced by the columnar presentation of stimuli. This possibility exists both here and in the experiments of Durding et al. Experiment 1 provides a partial refutation of this argument in that lists and primitive lists were still the most frequently occuring organisational structure of the randomly presented picture cards. It was on the second attempt at organising the cards that the majority of the more complex organisational structures, particularly hierarchies, were produced. Tables were rarely produced by subjects in Experiment 1.

6.4 Experiment 3: Organising Data 3

6.4.1 Introduction

Experiment 2 found that children had difficulty in organising sets of words into tabular and hierarchical organisations. Hence, the next experiment was designed to determine whether these organisations could be constructed when the structure of each word set was made explicit. The objective of this third experiment was, therefore, to investigate the effect of providing a pre-specified organisational structure into which the words could be slotted on young children's semantic organisation of groups of words. Again this work followed that of Durding et al.(1977).

It was hypothesised that the failure of young subjects in Experiment 2 to use a range of organisational structures, as the material demanded, was due either to the lack of familiarity with the more constraining organisational structures, or the limited cognitive ability of many subjects to work with more than one dimension at a time, as would be required in the tabular structures, in particular. Experiment 3, therefore, asked subjects to organise the same word sets as in Experiment 2, but this time the words were to be placed in skeletal structures which made apparent the pre-defined semantic structure of each word set.

6.4.2 Method

Subjects

The subjects were 52 school children aged between 9 and 11 years, all members of a either a third or a fourth year class of a junior school. Subjects were tested for their reading ability (McLeod, 1970), and for their non-verbal ability (Raven, 1956). These subjects did not participate in Experiment 1 or 2.

Materials

The materials were the same word sets as used in Experiment 2 with exclusion of the control condition, random word sets, as it was not possible to draw an organisational structure for these arbitary sets of words. A skeletal diagram consisting of a system of boxes and non-directional links, into which the words were to be placed , was presented below each word set. The diagrams appeared as in Figure 6.1 but without the words in place. The diagrams were placed below the word sets as the task sequence would suggest. Ordering of stimuli was randomised among subjects.

Procedure

Subjects were tested in their two class groups. A booklet containing four word sets, each as a column of words representing one of the four pre-defined organisational structures (lists, hierarchies, networks and tables), with the appropriate skeletal diagram highlighting the structural organisation of the word set below, was presented to each subject. The two groups of four word sets, which comprised the booklets, were given out alternatively to the children in the class. Thus neighbouring children within a class worked on different word sets.

Instructions to the subjects were as in Experiment 2 with the additional description of the skeletal structure and the use that the subjects were to make of it. They were told that each box represented the space to be occupied by one of the words on the page above the diagram. The lines joining one box to another showed that the two words were related to each other in some way. They were asked to sort the words into an order which highlighted the relationship between them, and they were to put each word into the appropriate box.

Subjects worked through the four examples at their own pace, which took from 25 to 50 minutes. Consistent with Experiments 1 and 2, time-on-task was not taken as a performance measure.

6.4.3 Results

Scoring

Two scoring techniques were employed, as in Experiment 2.

Simple scoring technique and analysis An initial simple analysis assessed the type of organisational structure chosen in each instance by the subjects, with no reference to the accuracy or semantic sufficiency of the subjects' work. The subjects' organisational structures were, therefore, classified into six categories; lists, hierarchies, networks, tables, primitive lists and others as defined in Experiment 2. The seventh category, defined-random, from Experiment 2, was not appropriate here as each word set had a pre-defined structure. Again these categories described 100% of the subjects' organisations. The results of this analysis are to found in Table 6.4.

Table 6.4 shows the frequency of each type of subject organisation for each type of pre-defined structure. Only 39% of the word sets were organised in a way consistent with the experimenter's pre-defined structures. There is a strong preference for list structures: 57% of all word sets were organised in this way. Subjects organised 92% of the list word sets into list structures, but were less successful in using the other three pre-defined organisations. Only 21% of hierarchies, 39% of networks, and 6% of tables were detected.

Table 6.4

Percentage frequency of each type of subject organisation for each type of pre-defined organisation in Experiment 3. (Simple scoring technique. N = 52)

	Pre-defined Organisation				
Subject Organisation	List %	Hierarchy %	Network %	Table %	Total %
Lists	**92**	21	48	67	57
Hierarchy	0	**21**	0	0	5
Network	0	0	**39**	4	11
Table	0	0	0	**6**	1
Primitive List	4	52	12	21	22
Other	4	4	0.5	4	3

Figures in bold indicate the % match between pre-defined organisational structure and the subjects' organisation of a word set. % are rounded to the nearest whole number.

Complex scoring technique and analysis The second, more detailed scoring technique, which assessed the degree of match between subject responses and the experimenter's pre-defined structures, was applied here as in Experiment 2. An analysis of variance confirmed the findings of the simple analysis, in that subjects responded with varying success to the four types of data organisation ($F=116.5$; $df=3,150$; $p<0.0001$). Mean scores for the degree to which subjects' organisations matched the pre-defined structures are shown in Table 6.5. Multiple paired comparisons using Tukey's HSD test are also indicated in the Table. Hierarchies and tables did not differ from each other, but they did differ from both lists and networks which, in turn, differed from each other.

Table 6.5

Mean percentage score for the degree to which subject organisation matched the experimenter's pre-defined structure. (Complex scoring technique - maximum achievable score 12. N = 52).

Mean Degree of Organisational Match	Pre-defined Organisation			
	List	Network	Hierarchy	Table
mean% score	90.3	65.6	32.9	36.1

Performance contrasts in Expt. 3. Conditions joined by a common line did not differ from each other, according to Tukey's HSD test.

6.4.4 Discussion

In Experiment 2 the two scoring techniques gave very similar results and it could be argued that one of the techniques was redundant. In Experiment 3, however, there were contradictions between the analyses. The simple analysis, which asked whether the subjects recognised the inherent structure in the word set, concluded that hierarchies were more easily recognised than tables (Table 6.4). But in the more detailed analysis, where the child's ability to match his or her solution to that provided by the experimenter was taken as the criteria of success, then hierarchies faired less well than tables, as is shown in Table 6.5. This apparent contradiction can be seen in terms of the relationship between lists and tables. Tables are lists on two dimensions; the category relationship was represented in the columns, and the semantic association occured across the rows. Many children were able to work along one or other of these dimensions but were unable to work in the second dimension. Alternatively, they may have felt that they had successfully completed the task once a list was produced. The production of a list organisation would produce a score of zero under the first scoring technique, but a score of 3 (25% match) on the second scoring technique. This cumulative addition of small scores increased the overall mean success rate of subjects' responses to tabular structures.

This incrementation did not occur for hierarchies, where the failure to recognise category labels had an equally damaging effect on either scoring system, and the default organisation 'lists' did not provide a useful partial solution to the problem of organising these word sets. This point appeared to be apparent to the subjects themselves. Subjects reverted to list structures in 21% (Table 6.4) of cases for hierarchical word sets as compared to 67% of cases for tabular structures. Over half the subjects (52%) who failed to recognise the pre-defined hierarchical nature of a word set organised that word set into a primitive list or pairing.

It seemed legitimate to maintain both scoring techniques as each provided information about the children's abilities to handle data. In particular the second scoring technique, hinted that subjects were having less trouble with tables than at first thought, even though it appeared to be limiting the subjects because it demanded that they reconstruct the same semantic relationships as the experimenter. The results from the second scoring technique appear reasonable given that children meet tabular data structures on a day-to-day basis in school, and some level of competence should be anticipated.

Thus it can be argued that priming the subjects as to the nature of the word set organisation does make a wider variety of organisational structures available to young subjects, and the subsequent improved performances are statistically reliable. These points will be considered further in the General Discussion.

A comparison of these data with the results of Durding et al. (1977, simple scoring technique only - Table 6.4) again showed that the young subjects performed less well overall than adults. One point of discrepancy between the two patterns of scores remained the comparatively greater ease with which the young subjects handled networks (39%) as opposed to hierarchies (21%), compared to adults (69% and 94% respectively). In the second experiment by Durding et al. a further qualitative difference was apparent. Adults had minimal difficulty in using a provided tabular structure (87% partially correct responses) and showed the largest improvement in correct responses over the first experiment on this type of organisation. However, these young subjects were still having considerable difficulty with tables (6% correct responses), when the simple scoring technique was employed. As argued earlier, the difficulties with tabular structures were less apparent when the more complex matching technique was employed to score the responses.

Durding et al. (1977) commented that the failure of their adult subjects to successfully negotiate the network word sets could be explained partially by the multiplicity of choice available in the locations for words (number of boxes to be filled), while only one of these locations could result in a correctly structured net. This argument is confusing because, although keywords (words with multiple meanings in the net) needed to placed on significant nodes (nodes which are at the junction of pathways), associated words (single meaning) could frequently occupy one of several locations and still allow a successful reconstruction of the net. It is also difficult to understand why they do not consider the identification of superordinate category labels in a hierarchy as equally constraining on the subjects.

Despite the problems which might ensue from the misplacement of a word with multiple meanings in a network, or a superordinate category label in a hierarchy, the constraining nature of the skeletal diagram was an important factor in the successful completion of any one type of organisation. Indeed our evidence suggests that in all types of organisation, except lists, the skeletal diagram made our young subjects pause for thought. Their deliberations resulted in one of three main strategies or approaches to the problem at hand. The first approach was to order the words without recourse to the diagram, most often into lists or primitive lists. These lists were then placed word by word into the skeletal structure, but because the skeleton was not congruent to the organisational structure they had elected to use, there was no obvious starting point for these entries. An arbitary entry point was therefore selected, and words were entered along a linear pathway ignoring the tie lines which indicated relationships, until all the boxes were full. Comments on the sheets by a number of children indicated that they were not satisfied with their solution of the problem, that is they knew they were in error, but that they could see no other solution.

A second approach was used when the young subjects were cognizant of the skeletal structure but, in completing the diagram, one of the keywords was misplaced (multiple meaning words in networks; category labels in hierarchies), possibly because of a lack of pre-planning or entering material into the skeleton before all the relationships had been established. In that situation subjects were inclined to alter the skeletal diagram, breaking links where they felt no relationship existed and forging new links where appropriate. The final approach, the most appropriate strategy, occurred when subjects were cognizant of the skeletal structure and actively reworked their organisational structure to fit the skeleton. In the case of these young children both reworking and redrawing of the structure frequently occured for the same word set.

The results of Experiment 3 suggest that young children are capable of constructing a range of organisational structures when the nature of the structure required is made apparent to them.

6.5 Experiment 4: Retrieving Data 1

6.5.1 Introduction

In Experiment 4 the investigation questioned the ability of young children to access information from a variety of completed organisational forms.

6.5.2 Method

Subjects

Subjects were 50 children aged between 9 and 11 years of age, all members of either a third or a fourth year junior school class. Subjects were tested for their reading ability (McLeod, 1970), and for their non-verbal ability (Raven, 1956). No subjects in this experiment had taken part in the previous experiments.

Materials

The materials consisted of three word sets of 10 or 12 words each, and were the same word sets as used in the previously described experiments, with the exclusion of the words organised into list structures and the random words, which acted as the control in Experiment 2. List word sets were excluded because they offered little scope for interrelational questions: each list was semantically isolated from the other two lists in the word set. Two separate, but similar, sets of stimuli material were developed. There were, therefore, two word sets corresponding to each of the three chosen organisational structures.

Each word set was placed in its appropriate skeletal structure and appeared at the top of the page (as in Figure 6.1). A number of questions, pertinant to the relationships in the word set, and with appropriate spaces for answers left blank, appeared underneath the organisational diagram. This was the reverse of the presentation layout in Experiment 3, but it was consistent with task sequence order. Number of, and type of, questions were used with the same frequency, as far as possible, across the pre-defined organisational structures. For example, a simple sub-category question appeared on all sheets:

Hierarchy: How many games are shown on this sheet?

Network: How many actions are shown on this sheet?

Table: How many people are shown on this sheet?

A more complex question might ask:

Hierarchy: What have cricket and netball got in common?

Network: What have pat and june got in common?

Table: What have road and court got in common?

In all, six questions, resulting in seven answers as one question required two answers, were required for each type of data organisation. Each subject received a booklet containing an example of the three experimental stimuli. The presentation order of the stimuli was randomised for each subject.

Procedure

Subjects were tested in their two class groups. A booklet containing three word sets was presented to each of the subjects. Each booklet placed an appropriate word set into one of the three pre-defined organisational structures, hierarchies, networks or tables, and this organisational structures was accompanied by the relevant target questions. The two groups of word sets were given out alternatively to the children in the class. Thus neighbouring children within a class worked on different word sets.

The subjects were told that the words at the top of the page, in the boxes, were related to each other. The relationship between the words was indicated both by the lines linking any two boxes together. The tie-lines between boxes were bi-directional. The subjects were then asked to complete the questions below the diagram. It was emphasised that the answer to each question could be found by looking at the diagram and checking the relationships between the words found there.

Subjects were told to work at their own pace. It was emphasised that they could have as many tries as they wanted before coming to a final decision but after they had turned over to the next example they were not to go back. Subjects worked through the three examples at their own pace, which took from 10 to 20 minutes. To maintain cross-experiment consistency time-on-task was not taken as a performance measure.

6.5.3 Results

Scoring technique and analysis Subjects were accorded one mark for each correct response and could, therefore, achieve a minimum score of zero and a maximum score of seven for each word set. Table 6.6 shows the mean scores for correct query responses for the three pre-defined data structures. Subjects had moderate success in extracting meaning from each of the three pre-defined organisational structures. Scores for responses to hierarchies (47%) and tables (49%) were little different from each other, but networks gave a slightly higher success rate (55%).

An analysis of variance of the query response data indicated a main effect of organisational type ($F=3.15$; $df=2,96$; $p<0.05$). Multiple paired comparisons (Tukey's HSD test) between mean scores for each of the data structures failed to reach significance ($p>0.01$) although a trend was discernable. There was a strong tendency for performance scores for networks to be better than for hierarchies ($p<0.05$); although the difference failed to reach the acceptable level of significance advocated for paired comparisons (Meyers and Grossen, 1974). Performances using tables were not statistically distinguishable from those of either networks or hierarchies.

Table 6.6

Mean percentage score for correct query responses for each of the three pre-defined organisational structures. (N = 50)

Mean Correct Response Score	Pre-defined Organisation		
	Network	Hierarchy	Table
mean% score	55	47	49

Performance contrasts in Expt. 4. Conditions joined by a common line did not differ from each other, according to Tukey's HSD test. Conditions joined by a broken line just failed to reach significance at the 0.01 level.

6.5.4 Discussion

Tentative comparisons can be made between these data and those of Brosey and Shneiderman (1978), who tested the relative ease of data extraction from simplified tabular and hierarchical data structures for university undergraduates. They used two tasks: execution of queries from the data-base, and the commitment to memory and recall of the complete data structure after the query task. Only the first task, execution of queries, has relevance to this present study. On this task Brosey's adults found it easier to extract data from the hierarchical structure rather than from the table. This finding was confirmed for data extraction from a larger data-base organised into each of the two structures, table and hierarchy.

These findings are less directly comparable to Experiment 4 than those of Durding et al.

(1977) were to Experiments 2 and 3, but points can be raised with caution. The caveat is that the reduction in task difficulty for the young subjects in Experiment 4 was so much greater in comparison to the adult study than it was for the initial experiments. However, young subjects again performed less well than adults, but equally importantly there was a qualitative difference in responses between adults and young subjects, the latter preferring the tables(49% correct) and hierarchies (47%)equally difficult, while the adults were more adept at using hierarchies (tables 70%, hierarchies 78% - approximate derived figures).

6.6 A Comparison of the Experimental Results

In order to allow comparisons across these experiments, the reading ability and non-verbal ability of each subject in each experiment was assessed prior to taking part in the organisational task. The group mean age and test scores are shown in Table 6.7.

The data from Experiment 1 were not of an equivalent form to the data in Experiments 2, 3 and 4 and, although qualitative comparisons are made, where possible, these data did not form part of the statistical analysis across experiments.

A comparison of the data from Experiments 2 to 4 showed an overall improvement in performance for the young subjects as the task changed from ordering data with no guidance; to ordering the word sets with an explicit statement of the structure to be used; and, finally, to extracting meaning from the pre-ordered word set. An analysis of variance of the percentage correct scores for the three organisational structures (hierarchies, networks and tables) common to all three experiments, indicated main effects of experimental condition ($F=7.86$; $df=2,137$; $p<0.001$) and of organisational structure ($F=62.72$; $df=2,274$; $p<0.0001$). There was also a strong interaction between experimental condition and organisational structure ($F=7.56$; $df=4,274$; $p<0.0001$). The pattern of performance was complex, however. Multiple paired comparisons (Tukey's HSD test) of the common structures, across the three experiments, confirmed that networks were handled more easily than hierarchies ($p<0.01$), and than tables in the first two experiments ($p<0.01$) but in Experiment 4, although networks proved easier to extract information from than hierarchies ($p<0.01$), there was no reliable difference in performance in the extraction of data from networks and tables.

Table 6.7

Ability profiles of the children for Experiments 1 to 4.

	Mean Age Years	Mean Reading Raw Score	Mean Non-verbal Raw Score
Experiment 1	10.02 (0.6)	18.7 (7.9)	16.1 (4.0)
Experiment 2	10.06 (0.7)	21.5 (5.6)	16.2 (4.1)
Experiment 3	10.03 (0.5)	20.5 (9.8)	16.8 (5.3)
Experiment 4	10.06 (0.6)	20.4 (10.0)	16.2 (5.0)

S.D. in brackets.

The results suggested improvements across all types of structure for Experiment 3, as compared to Experiment 2, and indeed, the provision of a skeletal structure in Experiment proved to be an aid to subjects' recognition and use of the network organisation ($p<0.01$). Although the multiple paired comparisons showed that the improved performances in Experiment 3 for hierarchies and tables ($p>0.05$) were not reliably different from those recorded in Experiment 2. The pattern of overall improvement was not maintained in Experiment 4. Subjects were more successful at using, rather than building hierarchies and tables, but it appears that it is easier to construct a network when primed (Experiment 3) than to either produce an unprimed network (Experiment 2) or to extract information from it (Experiment 4).

The lack of improvement when using networks in Experiment 4, compared to Experiments 1 and 2, can be partially explained by the failure of the young subjects to complete questions which required more than one answer. As was argued in Experiment 2, when considering the failure of subjects to organise tabular data, these subjects felt that a single description of the word JUNE was sufficient and rarely gave a second meaning. In this sense the subjects were responding in a similar manner to all three structures in Experiment 4. It is difficult not to conclude, however, that subjects were treating networks as lists for much of the time and failing to see cross relationships.

Performances on tables improved across the three experiments. Young subjects found it easier to access rather than construct tables with no priming ($p<0.01$) as was shown by a comparison of scores for Experiments 2 and 4. Experiment 1 had already confirmed that young subjects found great difficulty in constructing tables. The difference in performance scores between Experiments 2 and 3 just failed to reach significance ($p<0.05$; operating a significance level of 0.01 for paired comparisons), although the difference between these last two experiments did confirm the trend of improved performance when using, rather than constructing, tables.

Comparison of performance for the young subjects working with hierarchies placed similar emphasis on the improvement in performance between the task of constructing hierarchies, whether primed or not, and the task of accessing information from the data structure. Paired comparisons indicated reliable improvement in performances between Experiments 1 and 3 ($p<0.01$) and between Experiments 2 and 3($p<0.01$).

Table 6.8 presents correlations between task performance (complex scoring technique) and ability level for Experiments 2, 3, and 4. The tasks in all four experiments were inherently classificatory; such tasks could legitimately be expected to draw on non-verbal abilities (Bruner, Goodnow and Austin, 1956), and, following the work of Turner, Scullion and Whyte (1984), also be related to reading ability. In Experiment 1, level of complexity of organisation offered, a gradation from primitive lists to hierarchies and tables, was related to reading ability ($r=0.41$; df 45; $p<0.01$) but not to spatial ability ($p>0.05$), although spatial and reading abilities were themselves correlated ($r=0.36$; df=45; $p<0.02$). There was therefore an ability componet to the level of performance on this organisational task.

Table 6.8

Correlations between abilities (Reading Age and Non-verbal Ability) and task performance for the three pre-defined organisational structures common across Experiments 2,3 and 4.

Ability	Experiments	Pre-defined Organisation: Hierarchy	Network	Table
	2	0.294	0.149	0.198
Reading	3	0.515***	0.538***	0.237
Age	4	0.269	0.528***	0.438**
Non-verbal	2	0.058	-0.172	0.004
Ability	3	0.476***	0.634***	0.249
	4	0.350*	0.448**	0.525***

Level of significance of correlation: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

In Experiment 2, the most striking finding of the analysis was the failure of reading and spatial abilities to explain the performance scores recorded for each organisational type ($p>0.05$). There are two possible contributary factors to these results. As can be seen from Table 6.7, the range of ability in this experimental group was small in comparison to that for experimental groups 3 and 4 and this fact may well have disguised any relationships between ability and performance. This argument might also provide an explanation for the results in Experiment 1. The children in this group showed greater variation in reading ability than non-verbal ability, and it was the former ability that correlated with the task performance scores. It is possible that further studies on selected groups of good and poor readers, and children exhibiting good and poor spatial skills, would further elucidate the relationships between a range of abilities and task performance.

The lack of correlation may also have been partly due to both ceiling and floor effects as a result of the high performance of the vast majority of the children when working with lists compared to a very poor performance by the majority when working with other structures. Although one might have expected the more gifted child to use a greater variety of organisational structures than their weaker peers this was not the case, list structures were the predominant organisation used. However, those who performed well on constructing list structures also performed well on each of the other three organisational structures ($p<0.05$).

The results for Experiment 3 showed that success in organising lists, hierarchies and networks were all correlated to ability levels, but this was not so for tables. In each case ability level is more predictive in the success of reconstructing hierarchies ($p<0.001$)and networks ($p<0.001$) rather than lists ($p<0.05$). This suggests that list structures were readily available to most of the subjects. The lack of any relationship between abilities an the reconstruction of tables is difficult to explain. There was a relationship, however, between the successful completion of tabular organisations and both hierarchies ($r=+0.35$; $df=49$; $p<0.02$) and networks ($r=+0.33$; $df=49$; $p<0.05$), but not between tables and lists ($r=+0.26$; $df=49$; n.s.). This hints at an ability component in the successful completion of tabular structures but the conflicting data may well be a result of the dual nature of the table, in that it could be seen both one (e.g. list) and two dimensionally (e.g table).

In Experiment 4 success at responding to questions all three data structures was related to non-verbal ability (Table 6.8), while responding to questions on networks and tables was correlated with reading age, although this relationship did not hold for hierarchical structures.

Successful completion of the task on any one of the structures was related to success on each of the other structures; thus hierarchies were related to success with networks ($r=+0.49$; $df=49$; $p<0.001$) and with tables ($r=+0.43$; $df=49$; $p<0.01$); and this relationship held for networks and tables ($r=+0.43$; $df=49$; $p<0.01$).

Comparisons across the three experiments (Experiments 2, 3 and 4) produce no clear picture of the influence of ability on the rate of success children might achieve in either setting up or extracting information from the different data structures (Table 6.8). This result may well have been due to the low success rates achieved when working with hierarchies and tables. The construction and extraction of information from networks was strongly related to ability levels. Success in constructing hierarchies was also related to both non-verbal and reading ability but, extraction of meaning from a hierarchy showed reduced dependence on non-verbal ability ,and no influence of reading ability at all. Tabular structures show the reverse pattern to hierarchies. In Experiment 4 ability components appeared highly significant but these relationships were not present in Experiment 3.

One possible explanation for this reversal is in the very obvious need to clearly sort out the relationship between objects and to think spatially in order to successfully place material into a hierarchy. A misplaced superordinate object will have repercussions for the construction of the whole structure. Although a four by three table is also a highly spatial structure, there is no one critical point of entry into the diagram. A subject who started to insert the experimenter's row objects across the columns would find difficulty in placing all the objects, but the cumulative error would be far less punitive than when constructing a hierarchy.

6.7 General Discussion

The experiments were designed to explore the ease with which young children (9 - 11 years of age) could construct and extract data from a variety of organisational structures. This work was stimulated by the rapidly increasing use of computer-based information-handling packages in schools, and extends the conclusions reached by Durding et al. (1977) and, to a lesser extent, by Brosey and Shneiderman (1978).

Experiments 2 and 3 encourage us to approach the use of information-handling packages with caution. Unlike Durding's undergraduates, these young children were not very successful in discovering the inherent organisation of information, and showed a marked tendency to impose a standard structure (a list) on all data regardless of its inherent organisation. This result held true whether the subjects were primed to the appropriate organisational structure or not, although priming did improve performance on the non-list organisations. Hierarchies and tables were perceived as equally difficult by these young subjects, while networks were somewhat easier to construct; again a very different result from that of Durding et al. Their results showed that undergraduates were well able to reconstruct hierarchies, networks and, particularly lists. Tables were more difficult to reproduce, however.

The dominance of the list structure for the majority of children, and the poor performance on all other stuctures, in Experiment 2, masked individual differences and the influence of ability measures. Non-verbal and reading abilities were controlling variables for all data structures, except tables, in Experiment 3.

On a more hopeful note for those working with young children, Experiment 4 shows that the children were able to extract data from hierarchies, networks and tables, although scores hovered around the fifty percent success. We might, therefore, expect junior school children to use, if not construct, each of these organisational structureswith similar facility. A fifty percent success rate is still quite low, although it seems that in working with networks and tables at least, low scores might be partially attributed to the childrens' view that one answer is sufficient for any question! Again comparing these results to adult studies (Brosey and Shneiderman, 1978), the most striking finding was the near equivalence of performance on hierarchies and tables by the young subjects when asked to organise word sets (tables being the easier of the two), while adults found it far easier to work with hierarchies than tables. Non-verbal ability proved to be a key predictor of data extraction, although reading ability was also highly correlated with the successful use of networks and tables.

The pattern of organisation of picture sets (Experiment 1) follows more closely that of adults, and the children appeared to relatively proficient in the use of hierarchies, but such structures were generally produced on the second sort. Primitive lists and lists dominated the initial sort and were the most frequently occuring organisations overall. Bruner (1966) suggests that:

> "<u>At first the child deals with single features of a problem one at a time..... In time the child is able to deal with several alternatives simultaneously, hierarchically, and with the exclusive inferences made possible by hierarchical structure</u>." (pp. 323-324, 1966).

It may well be that these experiments were tapping a critical period of development for the children.

What do these findings mean for the use of information-handling packages in school? The difficulties experienced by these young subjects, compared to adults in similar circumstances, cannot necessarily be explained in terms of the develpoment of individual abilities. It could be argued that adult performances are a result of greater exposure, and therefore familiarity with, the types of structures used in these experiments. Equally, the low level of success may have resulted from the fact that the children could not see the purpose of a task which merely asked them to organise words. If the task had been placed in context then they might have been more successful. In either case, if information-handling packages are to be used in school, then teachers will need to ensure that children have had exposure to the relevant structures and have come to value the different methods of organising data, in order to achieve successful outcomes.

Research by Bransford (1979) adds another caveat to the application of these results. In his discussion of concept formation, he points out that in the majority of concept-identification experiments, participants had to identify which member of a set of known concepts the experimenter had in mind (e.g. red triangles, Bruner et al., 1956). Once the correct concept has been identified, or the experimenter made the rule explicit to the subject, problem solving became relatively easy (Anderson and Kulhavy, 1972). Bransford argues that this is a very different situation from that normally existing in the classroom for here the child is generally provided with the definition of new concepts rather than being allowed to discover them, and so the child fails to understand adequately or to transfer knowledge. Essentially, this suggests that data structures must be made transparent to children if they are to successfully organise or extract information from a particular structure, and this is best done by involving the child actively in the process of learning. Transparency of structure can also be aided by the manipulation of concrete objects, such as picture cards, as was shown by the children's relative success in producing un-primed hierarchies, but not tables, in Experiment 1.

Experiment 5 and the case studies, reported in the next two chapters, are investigations of the educational outcomes which occur when the children are encouraged to actively construct and use data-bases as part of their learning activities. In these investigations children's manipulation of data is placed in the context of a programme of topic-work.

CHAPTER 7

THE ROLE OF THE COMPUTER IN DEVELOPING CHILDREN'S CLASSIFICATORY ABILITIES: INFORMATION-HANDLING PACKAGES IN THE CLASSROOM

7.1 Introduction

The need to encourage children to develop information-handling skills, which are in turn based on well tuned classificatory skills, has already been outlined. In a world of inexorably increasing information we need to develop skills of information-handling rather than accumulating facts *per se* There is ample encouragement from the literature that such skills can be fostered. Mayer (1983) states that the cumulative research evidence shows that children's performances can be improved on virtually any task, given appropriate training or by changing the format of the task, although the effects are strongest for those children at critical points of development. The premise on which this study is based is that the use of readily available data storage and retrieval systems for educational microcomputers should actively encourage information-handling skills. This study asks what will be the effect, on children's minds, of exposure to information-handling software?

Although all information stores, including books, directories and computer data bases, are displays of organised data, the structure of that organisation is more overt in computer data bases. The importance of this transparency of the organisational structure to the efficient retrieval of information is highlighted in the work of Durding et al. (1977) and in a comparison of the results from Experiments 1 and 2. It is also recognised by book publishers who, in the last two decades, have worked hard to highlight the structure of both school and undergraduate texts through the use of colour, script style and skeletal summaries. The very method of constructing and interrogating computer data-bases, however, requires a clear understanding of that structure. This is not always so for a directory and certainly not so for retrieval of information from a book.

It might be hypothesised, therefore, that the transparency of structure in a computer data-base would facilitate the development of classificatory skills. Personal experience has shown that many teachers would not support this hypotheis. Comments following a demonstration to teachers of SEEK, the binary tree classification program used in this study, were less than enthusiastic. One teacher argued that he had been successfully conducting such work with children, using filecards and a knitting needle, for a number of years, so what argument could be put forward for replacing his home-made 'technology' with an expensive and scarce piece of equipment? This investigation in a very real sense was stimulated by that genuine and healthy scepticism. The aims of the study were fourfold:

1. To investigate whether children (9-11 years of age) would show a measurable improvement on a pre-post categorisation task through participation in a task involving classification of familiar objects (cheeses).

Hypothesis 1: Involvement in an information-handling project will lead to an improvement in children's classificatory abilities.

2. To investigate whether the children would be equally adept at using data storage systems exhibiting two standard methods of organisation, a binary tree and a matrix table. In the former the child is encouraged to think linearly but the latter requires a two-dimensional approach. On the evidence of Durding, Becker and Gould (1977) and the general view that operating uni- rather than bi-dimensionally would prove less difficult, it was anticipated that

the production of a binary tree would prove easier for these young subjects and, therefore, a more effective stimulant of the children's classificatory abilities. Experiments 1 to 3, outlined in the previous chapter, suggest that there will be no difference between the two types of organisation, however.

Hypothesis 2: Children working with different methods of data organisation will show a differential improvement in classificatory ability.

3. To investigate whether the teaching strategy employed, in this case teaching with or without the aid of a microcomputer and relevant software, would significantly influence the acquisition of classificatory skills.

Hypothesis 3: Children working within different teaching strategies will show a differential improvement in classificatory ability.

4. To investigate whether the teaching strategy employed, in this case teaching with or without the aid of a microcomputer and relevant software, would significantly influence the acquisition of specific knowledge.

Hypothesis 4: Children working within different teaching strategies will show differential aquisition of specific knowledge.

7.2 Method

Subjects

Ninety-one children, between 9 and 11 years of age, were assessed for reading ability

(McLeod, 1970), and for their non-verbal ability (Raven, 1956). Fifty-nine children, the members of two junior classes, were selected from this pool and assessed on their ability to complete a simple 'twenty questions' type categorisation task which is described more fully in the experimental procedure. Two classes were selected out of the original four tested, partly on organisational grounds, but also because there was a wide range of ability within each class and two age groups were represented.

Table 7.1

Ability Profiles of Children for the Four Experimental Conditions (N=10 in each condition).

	Mean age	Mean reading score	Mean non-verbal score	categorisation score
SEEK computer (**SC**)	10.5 (0.86)	19.4 (3.98)	17.1 (8.46)	8.2 (2.69)
SEEK control (**SN**)	10.6 (0.6)	19.2 (5.06)	17.6 (7.89)	8.6 (3.70)
FACTFILE computer (**FC**)	10.4 (0.49)	19.5 (3.17)	17.5 (7.01)	8.6 (3.92)
FACTFILE control (**FN**)	10.5 (0.61)	19.7 (4.76)	16.6 (9.73)	8.2 (3.21)

S.D. in brackets.

The three test scores were used to establish the four experimental groups, each of which contained ten children. The mean test scores for the children are presented in Table 7.1. While care was taken to match groups overall on age, it was also necessary to assign an equal number of children to each group from the third year (9-10 years of age) and the fourth year (10-11 years of age) junior classes to remove any bias from the extra year of schooling received by the older children.

Materials

The pre-post categorisation test materials Test materials for the pre-post categorisation consisted of two matched sets of twenty-four cards with a simple line drawing in black ink on white card. Each set of drawings differed on two dimensions, shape and number of objects. The shapes were equally divided into concrete objects, fruit or toys, and abstract objects, two or three-dimensional geometric shapes. Six examples of each category were represented: cards depicting fruit included oranges, apples, pears, bananas, grapes and strawberries. Within each set of cards the objects occurred singly or as a group. In Set 1, composed of fruit and three-dimensional shapes, the group size was two. In Set 2, which included the toys and two-dimensional shapes, each object occurred by itself and in a group of three identical objects. Two sets of test material were developed to reduce the effects of memory and material familiarity in the post-test situation.

The choice of stimuli was governed by a number of criteria. There was a clear hierarchy of dominance in the stimuli chosen; that is, subjects could be expected to attend to concrete objects first then to more abstract shapes, and finally to the concept of number (cf. Heidbreder, 1946; 1947). There was an equivalent number of stimuli in the groups formed on these criteria.

The stimuli were also governed by the criteria of 'imageability' and 'goodness of example.' Rosch (1975) states that categories appear to be represented in cognition not as sets of critical features with clear-cut boundaries, but rather as prototypes or clearest cases. The nearer an object is to the prototype the higher it will be rated as an example of the category. The selected toys and fruit used in constructing the test material were all ranked eleven or higher, out of a target population of sixty, on their 'goodness of example' (Rosch, 1975).

The 'imageability' of each stimulus card was also controlled. Snodgrass and Vanderwart (1980) argue that because there are so many ways to draw even the simplest object there is a need to use normative data on the characteristics of pictorial representations of concrete objects to achieve generally comparable data resulting from a categorisation task. Therefore, in studies involving such tasks, the concepts employed must be unambiguously picturable, and there must be a wide consensus about the name assigned to any object to be used for experimental purposes. Where possible the line drawings, all of the fruit and two of the toys, were selected from the standardised picture collection developed by Snodgrass et al., on the basis of ease of recognition and high agreement between subjects on the name associated with the picture. The four remaining toys and the geometrical shapes were either unavailable from published literature or inappropriate because of the American bias in the material. Consequently the additional stimuli were designed by a small team and tested for 'imageability,' on a small pilot population, in a manner similar to that of Snodgrass et al.

The computer programs. Two computer programs were employed in the study. The first program **SEEK** (ITMA, 1984), and its accompanying programs **THINK** and **INTREE**, allows children to set up and interrogate a binary tree, in which information is sorted or classified linearly through a series of yes/no answers. The second program **FACTFILE** (MEP, 1982) operates a matrix classification structure. Again children can set up and interrogate the data-base, but in this case the classificatory model is two-dimensional rather than linear.

The knowledge acquisition test. The knowledge acquisition test was designed to test the children's factual recall of the material discussed during the three week project on cheeses. The test was in two parts: a simple recall of the names of the cheeses in the project and, secondly, a more detailed test of the children's recall of the characteristics of each cheese. The latter test was constructed after the children had designed their data-bases and followed the format of the questions they themselves had used in the interrogating their data-bases.

The second part of the test consisted of nine questions. Each question required the child to select and name a cheese which would fit the description provided. The level of description, that is the number of defining features specified, varied between the questions. Three questions contained only one defining feature: '<u>Name a soft cheese.</u>' There were also three questions with two and three defining features each, for example: '<u>Name a white cheese with rind</u>' (two features) and '<u>Name a hard yellow cheese with veins</u>'(three features).

Questions were also governed by the number of possible correct answers, that is the number of cheeses which could fit the description provided, that were available as answers to any one question. This could vary from one to three cheeses. There were three groups of three questions with a choice of ,respectively, one, two or three possible answers. For example '<u>Name a red cheese</u>' required the child to name one specific cheese but when naming '<u>a soft cheese</u>' the subjects had two possible answers to choose from.

The presentation order of the questions was randomised for each subject.

Design

There were two between-subjects factors and one within-subjects factor in the experiment. The four experimental groups each received the pre- and post-categorisation tests along with all members of the contributing school classes. All subjects completed a work topic which involved classifying a range of cheeses. The children worked with the same adult who was not the experimenter. Two groups, further divided into two by age, operated a binary tree classification; one of these groups used the microcomputer with the **SEEK** program, the other group matched the structure of the computer program using file cards. The interrogative aspects of the program were provided by the adult working with these children. The two remaining groups, again sub-divided by age, completed the same task but operated a two-dimensional matrix classification; one group using **FACTFILE** on the computer and the other group designing their data-base with file cards and appropriate questions from the accompanying adult. There were in all eight working groups which combined to form two experimental conditions, **SC** (computer users operating the progran **SEEK**) and **FC** (computer users operating the program **FACTFILE**); and two control groups, **SN** (a group operating a **SEEK**-like classification without the computer) and **FN** (non-computer users operating a matrix classification which matched **FACTFILE**).

Procedure

Pre-post testing. The twenty-four cards depicting fruit and three dimensional shapes (Set 1) were used as stimuli in the pre-test categorisation task and Set 2 (toys and two-dimensional shapes) was used as the post-test stimulus. All subjests were tested individually.

In this task, a version of Mosher and Hornsby's (1966) 'twenty questions' game, the child was asked to discover which of the twenty-four cards the experimenter had selected and was thinking about. The experimenter placed one set of twenty-four cards face upwards on a table and the subject identified verbally the object depicted on each card. This removed the need for subjects to generate a precise name for each object, as would be required in many investigations involving a semantic task. Synonyms were quite acceptable as long as the object stayed within its category. This was particularly useful in naming the geometric figures. Shapes such as the elipse were more casually named by the young subjects than the square. Labels such as an oval or a squashed circle were generally offered by the children. The order of presentation of the stimuli was randomised for each subject although Lange and Griffith (1977), in their information retrieval tasks, had found no relationship between position of presentation and recall.

Once the subjects had identified each card satisfactorily, a neccessary pre-condition to limit any disparity in the two sets of stimuli, the child was asked to identify which one of the twenty-four cards the experimenter was thinking about. An unlimited number of questions could be asked to aid in the identification of the selected card but a response would be given only to those questions which could elicit a yes/no answer. The child was asked to generate both a legitimate and illegitimate question on this criterion. If he failed exemplar questions were given. Once the child understood the type of question which would elicit information the test proceded. Ten trials were conducted for each subject. The number and type of questions used to identify the target card were noted. The total task took between five and twenty five minutes for each child.

Developing classificatory abilities. Mielke (1968) has reminded us that when comparing the educational impact of different media only the media being compared can be different. All other aspects of the treatments, including the subject matter content and method of instruction, must be identical. This statement was born in mind in all aspects of the experiment. All fifty-nine children in the two sample classes were involved in a three week project in which the main task was to classify a range of cheeses. Care was taken not to distinguish the forty subjects contributing to the study from the remaining members of their class in order to reduce experimental bias. The children worked in groups of seven or eight and each group contained five experimental subjects.

All groups were led by the same adult who was not the experimenter. In the light of the findings of Kulik, Kulik and Cohen (1980) this provided a rigorous test of the robustness of any experimental results proceding from this experiment. Kulik et al., through a meta-analysis of previous media comparison studies, have shown that the positive effects recorded for technologically-based compared to traditional approaches to teaching, largely disappear when the same teacher produces all the treatments.

Each group was initially shown nine cheeses and, with guidance and following careful observation and description, identified a number of characteristics of each cheese. From this work the children constructed their classificatory criteria and each child was given one cheese to describe in detail using the agreed criteria. The remaining cheese, or cheeses, were described collectively by the group and one child recorded the group's deliberations. Four groups (**SC** and **SN** x the two age ranges) presented their work in the hierarchical mode of the binary tree and the remaining four groups (**FC** and **FN** x the two age ranges) developed a matrix data grid.

Once the classificatory criteria had been agreed each group took part in an introductory session to familiarise the children with the computer including the use of the disc drive, a new device to all of the children. Those experimental groups (**SC** and **FC**), who were to use either the **SEEK** or **FACTFILE** programs, proceeded to enter their data into the computer over the next week, and then they interrogated their newly-made files. The non-computer users (**SN** and **FN**) created hand-made grids with file cards and, with the aid of the adult, simulated the computer interrogation. This simulation consisted of the children asking retrieval queries in the manner of the computer user group and the adult responding to those queries. It was stressed to the children that their questions must be carefully formed, and the adult was instructed to give a nil, or 'don't understand' response to ill-formed questions. For example, a question asking for the 'best' cheese would be unanswerable if the children failed to specify the criteria on which 'best' should be judged.

In order to remove, or at least reduce, any perceptions of being treated differently, the control groups (**SN** and **FN**) completed a series of mathematical investigations with the computer. All activities took place in the school library, an area the children frequently used for small group work.

Assessing knowledge acquisition. Three weeks after the completion of the main project and the post-testing of classificatory skills, all of the children in the two sample classes were tested on their acquisition of the specific knowledge of the material discussed during the 'cheese project'. The children were tested in their class groups. The test was presented as a quiz to establish who could remember most about the cheeses we had been working with. The children completed the first part of the test, writing down all the cheeses they could remember from the project, and then handed their papers in. They were allowed five minutes for this task. The question sheet for the second part of the test was then distributed. It was emphasised that the answers to the questions were the names of the cheeses the children had experimented with, and that it was possible for one cheese to be the answer to more than one question. There was no time constraint to this part of the test and the children took between five and fifteen minutes to complete the task.

7.3 Results

Scoring

Pre-post categorisation test. Subjects were assessed on the mean number of questions required to identify the target card on each trial. Note was taken of the overall ratio of constraining questions to specific questions. A constraining question was defined as a question which eliminated several possible cards at a time. For example, the questions '<u>Is it a fruit?</u>' or '<u>Do children play with it?</u>' are both constraining questions as they effectively eliminate the geometric shapes. Specific questions and pseudo- constraining questions referred to individually identifiable cards. Such questions might take the form of '<u>Is it the teddy?</u>' or, more convolutedly, '<u>Has it got four corners and lines all the same length and right angles?</u>'

Knowledge acquisition test. On the simple recall task subjects could score a maximum of nine points if they could name all of the cheeses used in their project work. On the complex identification task, where subjects were asked to name an appropriate cheese to fit the description provided, subjects scored one point for each correct response and could achieve a maxium tally of nine points. No account was taken of spelling in assessing these answers. Overall each child could achieve a maximum score of eighteen points when the two parts of the test were combined.

From this same scoring technique, the data from the second complex recall test, was subdivided to give aggregate scores on the dimensions of 'level of description' (number of specified defining features in each question- one to three) and number of possible alternative answers (one to three). The maximum number of correct responses, for each subject, on these dimensions was three.

Analysis

Pre-post categorisation test A split-plot analysis of variance was performed on the mean number of questions per trial provided by each subject in each condition. The three factors were type of data organisation (between-subjects factor), teaching strategy (between-subjects factor), and pre-post classification test (within-subjects factor). There was a significant improvement in performance for subjects as a whole on the pre- versus post-categorisation task ($F=9.07$; $df=1,36$; $p<0.005$). The mean number of questions required to identify the target card was lower for the post ($X=7.13$) as compared to pre-categorisation ($X=8.44$) task, but there was no reliable difference in performance between the two methods of data organisation (**SEEK**, $X=7.62$ vs **FACTFILE**, $X=7.96$) or between teaching strategies (computer, $X=7.27$ vs non-computer, $X=8.31$). There was, however, a strong interaction between the teaching strategy employed and performance on the pre- versus post-categrisation task ($F=6.39$; $df=1,36$; $p<0.016$).

Further analysis showed that while the pre-categorisation scores for the computer and non-computer groups were virtually indistinguishable ($F<1$), and there was equally no difference between the pre- and post-test scores of the non-computer users ($F<1$), the computer users did not follow this pattern of results. This is clearly evident from the overall means of questions per trial shown in Table 7.2. There was a reliable difference between the pre- and post-test scores of the computer users ($F=15.34$; $df=1,36$; $p<0.0004$) and between the post-test scores of the computer versus non-computer users ($F=12.10$; $df=1,36$; $p<0.001$). The computer users not only showed improved performance in the pre- versus post-test situation, they outshone the non-computer users in the post-test situation although their performance had been indistinguishable from the latter group on the pre-test. Analysis of the strength of the improved performance registered between the pre- and post-test situation (mean post-test minus mean pre-test score) confirmed the the superiority of the computer user groups over the non-computer users ($F=6.39$; $df=1,36$; $p<0.016$).

Table 7.2

Mean Number of Questions per Trial for the Pre-post Categorisation Test. across Teaching Strategy.

	Pre-test	Post-test
Computer groups (**SC** and **FC**)	8.48 (3.28)	6.07 (0.95)
Non-computer groups (**SN** and **FN**)	8.42 (3.40)	8.21 (3.54)

S.D. in brackets.

A similar pattern of improved performance was apparent for the computer user groups (**SC** and **FC**) over the test period in the analysis of the type of questions asked by subjects ($F=23.67$; $df=1,36$; $p<0.0001$). Although there was no difference between groups in the pre-test situation ($F<1$), the computer groups asked a higher ratio of constraining to specific questions on the post-test than did the control groups ($F=12.00$; $df=1,36$; $p<0.002$). There was no improvement in the performance for the non-computer user groups over the period of the investigation ($F=2.83$; $df=1,36$; n.s.). This suggests that the computer groups were operating a classificatory strategy in the post-test situation. Indeed, Table 7.3 shows that in the post-test situation the computer users were asking slightly more constraining questions than specific questions. The non-computer users as a whole remained relatively reluctant to use this strategy, which suggests that the strategy was not available to them and that the children had not come to realise the benefits that it offered in solving the task at hand. It might be argued therefore that the computer users had been primed to a classificatory approach to the data by use of the computer software, but no such priming had taken place for the non-computer users. This argument would be consistent with the view of the superior transparency of organisational structure of computer versus non-computer data-bases.

Table 7.3

Mean Ratio of Constraining Questions to Specific Questions per Subject for the Pre-post Categorisation Test, across Teaching Strategy.

	Pre-test	Post-test
Computer groups (**SC** and **FC**)	0.52	1.06
Non-computer groups (**SN** and **FN**)	0.49	0.67

To further amplify the changes which had taken place between the pre- and post-test performances, the Pearson Product Moment Correlation was used to compare the relationship between individual student's performances on the pre-post categorisation task, with the general measures of reading and non-verbal ability. Pre-test scores were related to both reading ability ($r=-0.43$; $df=38$; $p<0.01$) and non-verbal ability ($r=-0.45$; $df=38$; $p<0.01$). The relationship between non-verbal ability and the categorisation task, in the post-test situation ($r=-0.34$; $df=38$; $p<0.05$) had weakened while that between the categorisation performance and reading ability had disappeared ($r=-0.18$; df=38; n.s.). These results clearly suggest that the improved performances on the post-categorisation task were a result of the experimental treatment which, in the case of the computer users, had allowed the children to either enhance or compensate for the initial personal abilities they brought with them to the teaching programme.

Knowledge acquisition test Analysis of variance of the mean number of correct responses for the combined learning test indicated that there was no difference in the performance of computer versus non-computer users ($F=1.22$; df=1,36; n.s.), nor between the two types of data organisation ($F=1.55$; df=1,36; n.s.). A more detailed analysis of the responses to the complex recall task showed that the number of correct responses was

Table 7.4

Mean Number of Correct Responses versus Complexity of Question Description in the Second Part of the Knowledge Acquisition Test

	Number of Defining Features per Question		
	One	Two	Three
Mean number of correct responses per subject	1.85	1.40	1.20

governed by the complexity of the questions ($F=6.56$; df=1,72; $p<0.02$). As the number of defining features in each question increased the number of correct responses decreased (Table 7.4). Paired comparisons confirmed that those questions with one defining feature were much easier to answer than questions with two ($F=5.99$; df=1,72; $p<0.01$) and three ($f=12.50$; df=1,72; $p<0.001$) defining features; although there was no significant difference between two and three defining feature questions ($F=1.18$; df=1,72; n.s.). The number of possible answers available for any one question did not influence recall performance (F2.67; df=1,72; n.s.).

These results are comparable to those of Shephard, Hovland and Jenkins (1961) who , in a simple classificatory learning task, found that subjects rapidly learnt, and were efficient at recalling, objects classified on one attribute, whereas progress was slow and difficult when the classification of stimuli to be learnt was based on two or more attributes. Shephard (1967) argues that problems involving such complex interactions of attributes are of great conceptual difficulty because of a combination of memory limitations and directed attention.

As has already been stated, the results of the knowledge acquisition tests were not influenced by the main experimental conditions; organisational structure and teaching strategy. Comparison of the recall performance for each subject with the general ability measures, proved more fruitful. Overall performance on the knowledge acquisition test was strongly correlated with reading ability ($r=-0.64$; $df=38$; $p<0.001$) but not with non-verbal ability ($r=-0.29$; $df=38$; n.s.). The conclusion to be drawn here is that the recall task was more a test of the children's memory capacity and reading ability than of the factual information acquired during the project!

7.4 Discussion

The evidence from this study confirm, as Mayer (1983) suggests, that it is possible to aid skills acquisition with judicious teaching/learning strategies. There were certainly overall gains in performance between the pre- and post-categorisation task but the strength of those gains was governed by the teaching strategy employed, computer users outperforming the non-computer users.

Why should this disparity in skills acquisition occur? As the categorisation task did not involve the use of a computer it might appear surprising that any effects should be discernible, nevertheless one might conjecture a number of possible explanations of this result. The first two arguments are suggestive of a disparity in the treatment received by the experimental and control groups. It might be argued that the data-handling packages on the computer exhibited a superior organisation to the hand-operated system generated in the study. Secondly it might be argued that the interrogative mode, in both SEEK anf FACTFILE, was superior to that operated by the adult worker with non-computer groups. Other explanations stem from the intrinsic nature of the computer. Were the children simply more motivated because they were using this new technology or, was there something more specific than an overall stimulus to work, in the nature of the interaction between the computer and the child?

In conducting the experiment great care was taken to match the operations off the computer to those presented by the machine and the appropriate software. This would have minimised if not removed any effects of the differences in organisation. Possible support for the rejection of this organisational hypothesis (Hypothesis 2) comes from the lack of disparity in performance between the children using the two different types of organisation; linear **SEEK** versus matrix **FACTFILE**. Interestingly this lack of disparity concurs with the results from Experiments 1 to 3 (Chapter 5) in which children produced similar performances levels when required to both organise and retrieve information from data presented in either a hierarchical and tabular structure. This same argument, the careful matching of the interrogative style of the computer by the adult worker, can also be put forward to reject the superior interrogative performance of the computer.

Are we left then with the motivational aspects of the computer as the sole cause of the improved performance in this study? Certainly the comments of the children using the computer were encouraging. The children appreciated the colour, the layout and the animated aspects of the programs which were either absent, or had to be provided by the children themselves, in the control situation. Those children in the control groups, using the computer for other activities, were also willing to complete the most mundane of tasks over and over again if the computer was involved.

There are perhaps other factors to be considered, however. Although care was taken to mimic the computer in all relevant operations, in human operations it is difficult to operate the same rigidity of control. The demands placed on the learner for precision in data presentation may be significant here. Each user must have thought very deeply about the material to hand not only to enter it into the machine but also to allow worthwhile questions to be asked of that data. This is no easy task, and both adults and children may initially have great difficulty in preparing material for entry into programs such as **FACTFILE** (Underwood, 1985).

Collaborative work, with teachers in a number of primary schools, highlights some of the difficulties faced in data-base use. For example, in producing a **FACTFILE** related to their project 'Sound in the Environment' upper junior school children (10 to 11 years of age) designed a number of field entries which did not exploit the full potential of the program. Such field entries suffered from an inability to maintain congruency of command (see Carroll, 1982; Underwood, 1983): for example, the production of a sound would be attributed to the object making the noise if it were a car, but to the human operating the object, in the case of a drill or a piano. There was a strong resistance to numerical coding even for those entries, such as noise level, which are inherently numerical. Numerical coding, despite its advantages for sorting activities, presents material in a more abstract form, and it does not seem surprising that these children were unwilling to let go the immediacy of a descriptive field entry, although not all children reject this form of coding.

In the present study the children operated five-point taste and group-preference scales alongside their descriptive fields, such as cheese colour. Children may not come to these decisions easily, however. In devising a 'Road Safety' data-base, a further group of junior children, numerically coded both traffic density and and road visibility. The children came to accept the need for such coding after several fruitless attempts to access information from the data-base in which the field entries were highly descriptive. Their information was too complex to put succinctly into the program because of the nature of the criteria employed. These children made an important breakthrough in their understanding of the way in which both data-bases and computers can be effectively used. In the latter case they came to appreciate that the computer is to be used with other tools, in this case worksheets displaying a full explanation of the field. This clear specification of the field is one of the key classificatory skills that had been encouraged during the experimental study. Secondly they learned that you often have to collapse or even throw away information in order to pick out essential patterns.

It is this latter process, the process of stripping data down to the essentials, that could be responsible for the differential improvement in performance of the computer and non-computer users in this study. This is a persuasive argument, for it feels right that the careful observation and naming of objects should lead to improved classificatory skills. Equally, although in both in the construction and interrogation of either a **SEEK** or **FACTFILE** data-base the program exercises considerable control over possible operations, the children may have felt a sense of of control when working with these programs which was not achievable when the adult took the role of the computer. Such a sense of control might lead to greater self-esteem (Papert, 1981; Golden, 1982), and be motivating in itself.

Anecdotal evidence confirms that children appear to produce differential responses to the authority of themachine compared to that of humans as Turkle has shown (1985) and pilot work to this project adds weight to her evidence. Video recordings of less able eleven year olds working with a drill-and-practice mathematics program shows that far from being castigated by the response to an incorrect answer, the children were highly delighted to see the computer displaying a harsh message of

"WRONG WRONG WRONG"

in bright red letters across the screen. These young boys produced a string of palpably incorrect responses in order to enjoy what appeared a savage telling off. It appeared that the ability to flaunt an authority figure was almost a cathartic activity which they enjoyed to the full. This is very similar to Turkle's children pulling out the batteries in the 'SPEAK AND SPELL' machine. The inability of the computer to truly punish might be one of its greatest advantages in the classroom.

One final explanatory factor might lie, yet again, in the nature of the interaction between the child and the computer. Alongside the 'power hypothesis' outlined above it could be argued that the swift response of the computer to the children's queries, particularly on more complex questions, might have led to a greater bonding between question and answer. Although the adult, under the control condition, would have provided rapid answers to simple searches there may have been delays on the more complex material. For the less able subjects in this experiment, the immediacy of feedback may have proved particularly important as answers could be provided before attention strayed and memories of the question under review faded.

A comparison of the effects of the computer condition on factual learning and classificatory skills is illuminating. While the computer groups produced significantly better performances than the non-computer groups in the latter case, there appeared to be no such benefit of the computer on information recall where performance was strongly related to reading ability. There are several possible reasons for this result. It has already been argued that the computer emphasises the organisation of data rather than the data themselves. If this is the case it could be argued that there is no legitimate reason for supposing that factual information should be preferentially available to the computer user groups. One flaw in this argument lies in the fact that the conjectured superior skeletal model of that data, provided by the computer programs, might have been expected to aid the organisation of the data in the child's memory and thus have aided recall, but this was not the case.

As there is abundant evidence to show that good organisation of material in memory is an aid to learning, the results of this experiment may be better ascribed to the limitations of the knowledge acquisition test. The results may well be attributable to the readability of the test material. The results on the test were also highly correlated to the reading test scores but not to measures of non-verbal ability. Even the low recall of cheese names by the less language proficient students could be attributed to a reluctance to put pen to paper, that is to commit themselves in a medium in which they have a history of difficulties and failures. The conclusion of this argument is that the results may tell us little of the true recall of the less reading proficient children, and that an individual oral test might have produced results at variance to those recorded here.

Also it was apparent that children certainly had difficulty in providing an appropriate answer as the questions became increasingly complex; that is when the question specified more than one defining feature of the cheese, as was predicted by the work of Shepard et al. (1961). Shephard (1967) cites considerable evidence for the failure of humans, in most cases adults, to use all the information available to them in making decisions. His argument is based on limitations in information processing, in that, when pressed to make decisions about multi-dimensional stimuli, humans generally have a tendency to simplify the problem , collapsing all information onto one single dimension, with the attendent loss of detail. Decisions are then made on this reduced information base. The decline in performance as questions increased in complexity might well have been a result of this simplifying of the problem to a single dimension by a number of the subjects, particularly the less able children.

One futher point should be made. Snow and Yalow (1983) suggest that one of the key questions in education concerns the relationship between intelligence differences and instructional treatments. The studies they discuss show that didactic teaching with paced individualised learning tends to wipe out intellectual differences, but that discovery learning tends to emphasis initial ability differences to the advantage of the more gifted child (Cronbach, 1977; Cronbach and Snow, 1977). The findings in this study do not fully concur with these results. Activities in the classroom, which involve the use of data-bases as a support tool to the exploration of a particular data set, are generally viewed as good examples of discovery learning (see Chandler 1983). Yet the less able children in the computer groups made strong performance gains on the post-categorisation task and appeared to be reaching a level of mastery commensurate with their more able peers. Such gains were not evident for the less able non-computer users, nor for the less able in either condition on the recall task.

One explanation of these results might be that although the classroom activities were explorative and, therefore, should have benefitted the more able, the rigidity of acceptable input to the computer provided the low ability children with a step-like sequence of moves which one would normal find in an individualised learning package. These children were, therefore, exposed to discovery learning with clear structure which proved very beneficial to them. Because the work on the computer did not specifically direct attention towards the acquisition of the specific knowledge of cheeses, the low ability children failed to make similar gains on the learning task, performing in a similar manner to the non-computer users, considerably below their more gifted peers.

The lack of impact of the two data organisations on children's classificatory abilities or, indeed, their ability to recall factual information, is congruent with the findings in the previous chapter. Children of nine to eleven years of age, do appear to treat hierarchical and tabular structures in the same way. This finding is at variance with that of Durding et al. (1977), working with undergraduates. Further exploration of the intervening age groups may provide an interesting insight into the individual's developing comprehension of data structures.

The arguments offered as a partial explanation of these results, imply that there are specific attributes of the medium, in this case the computer and accompanying software, which influence the way that information is processed in learning. In his criticisms of the effectiveness of new media in education, Clark (1983) has only been marginally less skeptical about 'media attribute research' than he was about 'media comparison studies'. He argues that although certain attributes of any given medium can model cognitive processes, as in Salomon's (1974) attention-directing studies, they can only serve as a sufficient but never necessary condition for learning. The rigidity of response acceptance, the explicit nature of organisational structures, the rapidity of response to a child's question, all attributes of information-handling packages, are what Clark calls operational vehicles for methods that reflect the cognitive processes necessary in order to successfully perform a given learning task. He would argue that there would be other ways of modelling the cognitive processes which did not depend on the computer, and that these ways may be as, or even more, efficient at stimulating learning, as was the case for Salomon's (1974) study.

Clark's concerns rise out of a perceived need to produce a general theory of learning, and, if the use of the computer is only a sufficient and not necessary condition for learning, the achievement of this goal is not furthered. Citing the work of Dixon and Judd (1977) comparing teacher and computer use of 'branching rules of instruction,' he concludes that most of the methods carried by the new media, can be performed equally well by teachers, and that no learning differences can be unambiguously attributed to any medium of instruction. In the face of such criticisms, based on extensive research evidence, it is perhaps important to reiterate that this study did find strong evidence of disparate skills, but not of factual learning between the computer and non-computer groups, even though the children had identical learning experiences for the first part of the study and experiences were matched on and off the computer in the second half; and, the 'teacher' was the same adult throughout.

One explanation for the disparity between Clark's views and these findings might be simply accounted for in terms of poor experimentation, it seems obvious from the research he cites that crucial variables, such as the impact of individual teachers, have been widely ignored. On a more pragmatic note, however, any successful method should be welcomed into the classroom, particularly when the attributes of that method are structural and therefore available for use by even the weakest teacher.

In summary the main findings of this study were that teaching strategy, but not organisational structure, lead to an improvement in classificatory ability. The recall of information post-study was related to reading ability rather than to either of the main experimental conditions. Whatever the underlying causes, the computer in this study did lead to improved performance on a simple categorisation task, and although it can be argued that binary trees can be easily constructed without a computer, there are gains to be made using the computer as part of the teaching and learning environment. Bruner, Goodnow and Austin (1956) consider the process of categorisation as essential to everyday life, for it enables us to make sense of the vast array of data impinging on our senses. Computer software designed to organise data can act as a stimulus to classificatory skills development. It provides the teacher with a package which is highly flexible and content-free, but with a well developed and proven structure.

CHAPTER 8

THE USE OF INFORMATION-HANDLING PACKAGES IN SCHOOLS: TEACHER AIMS AND CLASSROOM REALITIES

8.1 Introduction:

The Potential of Information Storage and Retrieval Systems

The argument has already been presented that the classroom computer can, and should, be used in more liberating and creative ways to stimulate children's intellectual capacities, rather than as a drill and practice machine. In the terms of Bloom's (1956) taxonomy we are discussing uses which place a high cognitive demand on children. Such uses go beyond the acquisition and comprehension of knowledge, encouraging children to apply skills and knowledge, to evaluate and make judgements, and finally to draw together disparate information into a whole, in order to solve problems. To achieve these goals the child is encouraged to use the computer as a tool, particularly a tool to amplify his own thinking. One such tool use is that involved in processing data.

The views of Gagné (1970) and Labbett (1985), that teachers and students are already steeped in the ways of the information processor (discussed in chapter 5), question the importance laid by many educators on the introduction of computer-based storage and retrieval systems into classrooms. What can they offer in educational terms that the book-based databases can not? Kelly (1984) states the computer is a most appropriate means of storing, retrieving and classifying information as it has the capabilities for processing large quantities of data at vastly superior speeds than anything that has been devised before. Here Kelly is arguing the machine's superiority on two characteristics, the encyclopaedic storage of data and the rapidity of access to that stored data.

Chandler (1984) questions this encyclopaedic view of data-bases, pointing out that the London magazine TIME OUT in 100 pages, provides all the entertainments currently available in the capital. To match this, PRESTEL's viewdata system would need to set aside 200,000 frames, a highly uneconomic proposition. He argues, as many others before (cf Bloom, 1956; Gagné, 1970), that it is not the collected data which is of great importance, for he believes facts are the least important factor in thinking and learning, rather it is the way in which data are used, knowing how to find, select, interpret and re-organise the material. The Schools Council (1981) put this succinctly when they pointed out, not only the growth in information, but the ready availability of that information to individuals. They argued that children needed to be able to search out relevant information, assess critically the ideas and facts offered and then to make use of those findings. It was not only this goal-directed purpose to learning that they felt was missing in many of our secondary schools, they also maintained that in institutions whose main concern was learning above all else, teachers found greatest difficulty in teaching pupils the skills of learning itself.

In Piagetian terms of course, the skills of learning are inherent in the child and cannot be taught, the teacher's role in such a classroom is to provide an environment in sympathy with the child's level of development in order that he can make appropriate intellectual leaps as efficiently as possible. The teacher has a far more active role in the Vygotskian (1978) and Brunerian (1983) classrooms. For example, in the Brunerian classroom the teacher's role is to provide a scaffold for children's problem solving. Here the teacher is a key interventionist, providing help when the child is in difficulty but standing aside when he succeeds, and generally supporting the abilities to select, remember and plan which are necessarily under-developed in the child (see Wood, Bruner and Ross, 1976). It is in this role of support facility that the data-base is seen as most useful.

"Computerised information storage and retrieval is capable of offering liberation from 'cluttered brains' and thus giving freedom to concentrate on the development of flexible

<u>thinking skills</u>" (Chandler, 1983, p.56).

This view equates with Rushby's (1979) classification of information-handling packages as emancipatory, in that they free the user from non-essential work.

Moreover the pragmatic argument that computer-based information systems are widespread in the world outside the classroom and, therefore, that there is a need to develop 'information literacy,' is quite powerful. Papert's (1981) third guiding principle of appropriate mathematics (but possibly also of education in general) is that of 'cultural resonance.' He argues that knowledge must make sense in terms of the larger social context, and that it must be valued by adults and not simply seen as a 'kid's thing,' which the adult population sees no reason to take or use themselves.

Chandler (1984) is particularly concerned that children should not only be aware of, and have access to, national and even international data-bases, they also need to be contributors to the store. He argues that, "<u>guided tours of someone elses frame of reference are not enough</u>" (p. 48). Children need to create their own systems for communicating information with one another, otherwise they will become alienated consumers of others' knowledge. Papert defined this as the 'power principle.' The learner must be empowered to perform personally meaningful projects.

As Olsen and Bruner (1974) have pointed out, direct experience develops skills about the activity involved in gaining information, whereas mediated experience (for example using a pre-packaged information store) develops skills in using the medium. Both are useful and provide information about the world, but for the majority of teachers the key educational goal is stimulating cognitive development and not training technical skills.

The premise that the child's cognitive performance will improve, over a wide range of measures if the educational experience builds upon the child's own experiences, is one which finds ready acceptance among practising teachers and theorists alike. Papert (1980) defined this as the 'continuity principle,' the first of his guiding principles for an appropriate mathematics, a principle which is the corner stone of most theories of learning and child development (see Wood, 1980). Publically available viewdata systems such as PRESTEL and, the non-interactive, CEEFAX and ORACLE, make only minor concessions to children. Many teachers have felt it more worthwhile and, it must be said, cheaper, to use disc-based simulations of the original packages, especially as children can generate their own PRESTEL-like pages. The TTNS (The Times Network for Schools), however, is a full information storage and retrieval system, which has the potential of national and international communication, and in which children can play an active part in building the data store. The use of such a package not only encourages children to collect their own data and prepare it for consumption by the computer, it has also encourages children to pose a range of questions of their own devising, which the machine can respond to, through an analysis of the children's own data, resulting in a representation of the data in an altered form (Kelly, 1984).

The introduction of TTNS into schools highlights one of the pitfalls of working with a powerful technology, however, that is the ease with which the individual is subverted by the glamour of the machine into trivialising education. In my own county one 'major' project undertaken using the facilities of TTNS was a national survey of secondary schools. The topic chosen for this costly operation was 'Pop Music.' The topic has of course immediate relevance to teenagers and it is quite possible that some useful mathematics came out of the project, but it is difficult to see what reasoned or evaluative statements could be made from questions of the type: 'Who is your favourite male/ female singer/ group?' This encapsulates Chandler's (1984) concern that educational institutions in Britain have responded to the ever increasing threat to the place of facts in education by adding to the curriculum something called 'information skills,' defined as the ability to 'handle' facts. He considers that the phrase itself has disturbing overtones because of the reference to 'skills' rather than 'strategies,' and the implied focus on 'information' rather than learning. Ellingham (1982) takes up this point when he argues that thinking about the computer in primary education (or indeed at any level of education) should not mean thinking about computers but thinking about education.

Sigel and Saunders (1979) have queried the assumption that a question-asking instructional strategy necessarily promotes thought. They argue that all the studies which accept the proposition that asking questions is 'good' are based on two implicit assumptions: firstly because it enhances problem solving skills; and, secondly because question-asking by the child reflects his or her thinking, while question-asking by the teacher promotes the child's thinking. They suggest that previous studies (see Sigel and Saunders, 1979) have not provided a systematic conceptual base for advocating the use of question-asking strategies as an instructional model, nor have they explained why questioning should enhance problem solving skills. Dillon (1982) and Wood and Wood (1983) are of the opinion that classroom questions delimit rather than stimulate inquiry, but this, of course, is when the teacher asks the questions.

One reason for using information-handling packages in the classroom is to encourage the children to ask the questions and not the teacher. Under these circumstances, the answer put forward by Siegel and Saunders to their own query, is certainly tenable. They argue that it is because inquiry can create discrepancy or a mismatch between sets of events that such an approach to instruction provides a framework for cognitive development. This view of problem solving as the resolution of uncertainty, in which ambiguity and paradox drives thinking, a vital engine for the development of the individual, is at the heart of many theories of learning and child development (cf Piaget, 1952; Bruner, 1966; Vygotsky, 1962; Papert, 1981).

However, it is not enough for children to ask questions, whether they are motivated by covert or overt hypotheses. It is also important that they come to appreciate that those hypotheses built on a foundation of constraint, rather than hypotheses strung non-cumulatively together (eg, the hypothesis scanning strategy of Mosher and Hornsby, 1966), are a far more effective problem solving strategy. Children operating an hypothesis scanning strategy can become confused and discouraged by the mass of disorganised information impinging on them and fail to see essential patterns in the data. It is argued that practice in inquiry, in trying to figure things out for oneself, encourages the rearrangement and transformation of data in such a way that one is enabled to go beyond the evidence and assemble new insights (cf Bruner,1973; Papert, 1981). Emphasis upon active learning encourages children to become autonomous and self-motivated thinkers, leading them to be constructionists, organising data, discovering regularity and relatedness, and avoiding the kind of information drift that is symptomatic of non-goal directed thinking, and which fails to recognise the potential usefulness of much of the data to hand.

The argument for the flexible thinker leads us back to societal needs. Bradshaw (1985) argues that there is mismatch between employer needs and the educational responses. While the latter focus on disciplines and vocational skills the former sees transferable skills and attitudes as more important. Although it is difficult to define such skills, he suggests that what employers are looking for are the skills of communication, co-operation and teamwork. One major firm itemises its priorities as a need for workers who can: set and achieve objectives; communicate and influence others; solve problems and set priorities; show leadership and work with others; and generate new ideas and better ways of doing things. Although Bradshaw's report is dealing with post-degree recruitment, the issues are relevant at a variety of levels. Essentially it is an argument for a problem solving approach to education, which is not content orientated, and which allows the learner to make decisions and to take on a variety of roles including project manager and team member. These are the central goals of programmes involving computer-based information-handling packages in the classroom.

In brief, therefore, information-handling packages are seen by many as one of the most effective ways of using computers in school. Firstly because the software exploits the full potential of the machine itself; as in the adult world, information processing by computer allows rapid and increasingly complex manipulations of data. Secondly, it offers the opportunity for children to collate and interrogate their own material from the environment. Finally, Goodyear (1985) argues that, prior to the advent of classroom computers, in any exploratory approach to data the amount of 'inauthentic' labour, that is work which is not intrinsically valued as part of the learning experience, was high. Children spent far more time on tasks such as completing simple computations or conducting frequency counts rather than thinking about the relationships within the data. This placed severe limits on the amount of data that could be manipulated, and downgraded the activity as an example of real-world research problems.

These last two points, in which students not only have ownership of tha data, as they have collected it, but are also able to use large bodies of data because of the emancipation of the child by the computer, each go some way to answer Weisenbaum's (1976) concern that the computer encourages the divorce of humans from the real world.

There are, it would seem, compelling arguments for using information-handling packages in schools, but are they really such effective tools in the classroom? In the following investigation, eighteen instances of classroom data-base use were analysed in order to identify the educational benefits, if any, which accrued from children's usage of such packages.

8.2 An Investigation of Teacher Intents and Classroom Outcomes when Information-Handling Packages are Used in the Classroom

8.2.1 Aims of the study

This study was an evaluation of the investigations undertaken by teachers and pupils using a number of computer-based information-handling packages in eighteen classrooms. This research sought to identify and compare the expressed aims and objectives of teachers using data-bases in the classroom across this wide age-range and, to identify the compatability, if any, between identified aims and classroom outcomes. For example, do teachers consider the development of hypothesis-testing strategies as an important cognitive outcome of the use of data-bases and, if so, do children, when using data-bases, develop insightful questions based on implicit or explicit hypotheses? In this analysis outcomes are restricted to *post hoc* analysis of data collated after the trial period by the teachers themselves.

In the next section 8.2.2 a conceptual framework for the analysis of the eighteen case studies will be established. This will be followed by a resumé of the sample studies in which the characteristics of each case study will be noted. The resumé will include a statement of the software used; notes on the content area of each project and the main roles taken by both the children and the computer during the project; and will also include a statement of the sources of data available to this analysis.

In section 8.2.4 a four-fold classification of teacher intents will be applied to the data from the case studies. A more detailed version of the same framework will also be used to describe the classroom transactions and outcomes for the sample studies in section 8.2.5. A comparison of intents with transactions and outcomes will then follow. The chapter will close with some concluding remarks about information-handling packages in schools.

8.2.2 A conceptual framework for classroom analysis.

An evaluation of educational outcomes *per se* is far from easy and the arguments for and against nomothetic and idiographic approaches to evaluation have already been discussed in Chapter 2. The use of technology in education can lead to a technological view of education, where success or failure is defined in terms of of the size of discrepency between intended and actual student performance; the matching of instructional sequences to individual student differences. The computer is well-suited for the role of collecting and analysing statistical indicators of performance towards such specified behavioural objectives.

The use of information-handling packages is seen in a rather different light by those supporting their use in schools (Adams and Jones, 1983; Chandler, 1984; Ross, 1984). Their views coincide with McClellan's (1972) definition of individualised learning, in which instruction is directed at the optimisation of students' own aims and no common objectives are given. The concept of the computer as a tool is in sympathy with a less teacher-directed education in that it can be used to expand the children's own abilities and allow them to achieve new goals: for example by increasing their working memory as an aid in problem solving when using data-bases; or by the encouragement of writing skills through the use of a text processor.

Kemmis (1978) argues that where students are not expected to attain common objectives, or if the instruction can not be defined in clearly graded steps, then a nomeothetic approach to evaluation will rapidly become unworkable. This study did not directly assess the 'amount' of learning, in the form of knowledge or skills, acquired by the pupils, rather it sought to identify the occurence of episodes and exchanges in the classroom which have been designated as leading to beneficial outcomes by educationalists , in order to ascertain whether the perceived potential of using such software in schools had been realised. The case study as a methodological approach shifts the emphasis from quantitative to qualitative evaluation and is in the hermeneutic tradition (cf MacDonald and Walker, 1975; Stake, 1980).

In developing a framework for the analysis of the eighteen case studies there was necessarily an element of hindsight. The analysis worked backwards from the effects or outcomes of the individual projects to the expressed aims of the teachers involved in each project. The study is in one sense highly subjective in that no independent observation was undertaken, the record for analysis is that of the teachers alone. This may be seen as a weakness of the study in that the effects of the media in education are frequently subversive and counter-intuitive, and it is necessary not only to look at the expected effects, as suggested by the aims of the teachers, but also the hidden curriculum of data-base use. Insights into this hidden curriculum must be gleaned from teacher descriptions, transcripts of interactions and support material, such as worksheets, all carefully pre-digested and selected by teachers for inclusion in their reports. In some cases individual discussions occurred, after the completion of the individual reports, which helped to clarify the more ambiguous statements of the teachers.

There were several reasons for undertaking this method of research. On a pragmatic level, it was impossible for one part-time researcher to monitor eighteen classrooms spread over a wide geographical area, within one calendar year. In addition, as all the teachers involved were submitting work for assessment, the researcher would have been viewed as part of that assessment process and this would have placed an additional strain on the teacher, and might have influenced the nature of the activities in the classroom.

Although the use of only teacher-reported and selected materials meant both a loss of control over the data and a necessarily limited spread of data, such a technique has already been productively used to analyse classroom outcomes (cf Wood, McMahon, and Cranston, 1980). This technique not only allowed teachers to record those activities that they felt were of value, in annotating the material, they were also able to explain why they had approached the work in a specific way and to articulate what they felt about the outcomes. Teachers often feel that objective educational evaluation misses the point of what is happening in their classroom, an argument frequently raised in the study by Wood et al. (1980).

One caveat which must always be applied to such an approach is that although the records of the teachers were meant to be evaluative, the element of self-evaluation would understandably lead to a bias towards the most productive classroom outcomes, and although specific weaknesses were identified, the picture most of the teachers provided should be considered rose-tinted. This in itself was not viewed as a weakness for it presented the work undertaken in its best light, that is it largely captured what the teachers saw as optimal performances, and provided a good basis for comparing the potential and the reality of data-base use in classrooms.

The extraction of intentions and outcomes of classroom activity from teacher reports is problematical, however, because not all teachers are adept at clearly articulating their goals or their achievements. Strake (1980) has developed a description-judgement matrix as an aid to planning classroom analysis, but it has also been applied retrospectively to evaluate educational outcomes (Harrison, 1985). The first dimension of the matrix is defined by time; antecedents, transactions and outcomes can be interpreted as relating to observations or judgements made respectively before, during or after classroom activity. The second dimension, the nature of response, relates to intents and observations (the description matrix) and judgements and standards (the judgement matrix). This, in a reduced form, provided the basis for the current analysis. Initially teachers' antecedent intents were identified (section 8.2.4) and these were then compared to the transactions and outcomes from data-base use noted in the classroom .

The *post hoc* nature of the data used in this analysis has already been noted. In addition, as the reports were produced for assessment, it appeared that some teachers specified aims quoted in the literature with little thought of classroom implications; they were not true intentions. Equally other teachers proved less able to articulate their intentions but nevertheless established a highly productive learning environment. It was with these cautionary notes in mind that the analysis proceeded.

8.2.3 The Sample

The survey sample included the full educational age-range from the earliest years (5-6 year olds) to secondary and further education (16-18 year olds). The sample was divided into three groups on the criterion of age: early primary (4 schools in the age range 5-8 years); later primary (8 schools in the age range 8-11 years); and, secondary/ further education (6 schools in the age range 11-18 years). In addition, one of the survey's secondary schools was a specialist school for children with learning difficulties. All the teachers involved in the study were on substantive courses (over 100 hours in length) in the use of educational computers. This meant that all the teachers were competent computer users, but not necessarily programmers, who valued the computer and wanted to use it effectively in their own teaching. The teachers themselves covered a wide range of academic interests although there was a preponderence of language/ arts specialists working with the younger children, while the proportion of science/mathematics specialists increased with increasing age range.

The content areas covered by these case studies was far ranging including support packages for computer aided design (CAD), careers counselling and the selection of reading texts, but the preponderance of projects were in the field of environmental science/ studies, drawing heavily on the disciplines of biology, geography and history. A brief description of each case study is presented below. Each study will be referred to by number to maintain the anonymity of the teachers and pupils.

Case studies CS1 to CS18: In each brief description of the eighteen case studies the age-range taught, the topic of the study and mode of use of the data-base have been noted. The nature of the data to be used in this analysis of teachers' intents and classroom transactions and outcomes, is also specified. In some studies, the only source of data was the teachers' own written comments, but many of the studies included exemplar worksheets and actual pieces of children's work. In one or two cases there are detailed transcripts of classroom interactions. A disc containing a copy of the data-base and a print out of its structure and contents was available for each of the eighteen case studies.

Secondary/FE (11 - 18 years of age)

CS1 An investigative local history project using the program HISTSEARCH with 13-14 year olds. The pupils used a ready made data-base; that is, they were involved in information retrieval and not organisation of the data. The role of the computer was to provide a legible printout of census material.

Data source for the analysis: Teacher's comments only.

CS2 A biology project investigating speciation of two island populations using INFORM. The project formed part of a spiral curriculum with work at each level of the secondary school; age range 11-18 years old. The pupils used a ready made data base to answer a series of research problems posed by the teacher.

Data: Teacher's comments plus extensive examples of the worksheets presented to each group of pupils.

CS3 A reference base for a craft design course using BETA BASE with 14-16 year olds. The pupils used a ready made data-base to identify specific materials needed to complete their designs.

Data: Teacher's comments only.

CS4 A reference base for careers counselling using BETA BASE with 16-18 year olds. The pupils used a ready made data-base to identify possible career pathways, including necessary qualifications and conditions.

Data: Teacher's comments only.

CS5 A project on health care investigating the children's own dental health using INFORM with 13-14 year olds. The pupils were involved in data collection, defining the structure of the data-base and in interrogating their package.

Data: Teacher's comments, examples of the data recording sheets and detailed specification of the interrogation of the data-base including both the questions asked, the steps of each sort, and the children's responses to each sort.

CS6 A reference base for reading books using FACTFILE with 11-13 year old slow learners. The teacher constructed the format of the data-base with these less able children but they were actively involved in collecting and entering the data into the pre-defined structure. Evidence of information retrieval was sparse.

Data: The teacher's comments only.

Late Primary (8 - 11 years of age)

CS7 A study of European Countries using FACTFILE with 8-9 year olds. The children were involved at all stages of the project from initial goal definition and data collection through to questioning the data-base. They also took on the role of curriculum organisers, preparing and carrying out a series of teaching activities with a parallel class of children.

Data: Teacher's comments plus the worksheets designed by the children to pass on their skills and knowledge to the parallel class.

CS8 A mathematical project developed to support the SMP mathematics scheme using FACTFILE with 8-9 year olds. The children were involved at all stages of the project from initial goal definition and data collection through to questioning the data-base.

The package was used both as an investigatory tool and also as a reference source to provide the data necessary to perform problems arising out of the SMP mathematics scheme.

Data: Teacher's comments only.

CS9 There were two projects in this study. The initial project called 'Ourselves,' was conducted using a hand-sort on a binary-selection punched card data store and was introduced to help children understand the nature of computer sorting processes. The second project, included two sets of environmental data, and operated using the SEEK program. Each study was investigative and involved these 8-9 year olds in the full range of activites from initial goal definition to interrogation of their various data structures.

Data: Teacher's comments, extensive transcripts and exemplar printouts of specific interrogations.

CS10 There were two projects in this study. The initial project on environmental studies used the MINIBEASTS program and involved these 8-9 year olds in the collection and input of data into a pre-defined structure, and the later interrogation of that structure. The use of this simple program was seen as an introductory step to the more sophisticated INFORM program.

The second project on community needs used INFORM. The children were not involved in the collection of the data but they did provide the format of the data-base and input the data, and they then interrogated the data-base.

Data: Teacher's comments, selected transcripts and tape recordings of the conversations around the computer between teacher and individual children, and between the children themselves, plus exemplar print outs of specific interrogations of the data-base.

CS11 A project on countries of the world using FACTFILE with 9-11 year olds. The study was investigative and involved the pupils in the full range of activites from initial goal definition to interrogation of the data-base.

Data: Teacher's comments, exemplar worksheets and a range of the children's own work arising out of the use of the data-base.

CS12 This was an investigative project on road safety using FACTFILE with 8-9 year olds. Pupils were actively involved in the full range of activities from goal definition, through data collection and organisation, to the resolution of the research question 'Where is the safest place to cross the road?'

Data: Teacher's comments plus examples of children's work arising out of the use of the data-base.

CS13 This was an investigative project on the planets using FACTFILE with 8-10 year olds. The teacher defined the initial goals based on work from the educational television programme Zig Zag. Children were involved in data collection and, with considerable teacher guidance, in structuring, producing and interrogating the data-base.

Data: Teacher's comments, exemplar worksheets and examples of children's work arising out of the use of the data-base.

CS14 An investigative project on modes of transport using FACTFILE with 8-10 year olds. The children were involved in data collection and interrogating the data-base. The teacher defined the project goals and format of the data structure.

Data: Teacher's comments and exemplar worksheets

Early primary

CS15 An investigative project on the topic of the children themselves using FACTFILE with 5-6 year olds. The children were involved in data selection and collection but the teacher designed the format of the data-base, input the data and, to a large extent, formulated the questions to be asked of the data-base.

Data: Teacher's comments only.

CS16 An investigative project about the children themselves using FACTFILE with 7 year olds. The children were involved in the full range of activities from goal specification to interrogation of their self-constructed data-base.

Data: Teacher's comments, exemplar sorts and a limited number of examples of the children's work arising out of the use of the data-base.

CS17 A project on trees using FACTFILE with 7-8 year olds. Initially two children designed the project, collecting the relevant data and specifying the organisational structure for the information package, which was then used by the rest of the class as a reference source in their environmental studies project.

Data: Teacher's comments and an exemplar worksheet.

CS18 An investigative project about the children themselves using FACTFILE with 6 year olds. The children were involved in data selection and collection but the teacher designed the format of the data-base, input the data and formulated all the questions to be asked of the data-base.

Data: Teacher's comments and an exemplar worksheet.

8.2.4 An analysis of expressed teachers' intents

The nature of the study required evidence that teachers showed at least some understanding of the potential educational value of data-bases. Intents were articulated by all teachers, and such intents, because they have been selected from an almost infinite number of possible objectives, are indicators of a teacher's educational priorities. The evidence from these lists is crude, however, because it does not differentiate between priorities, that is it does not indicate the emphasis which will be given to each intent only that that intent will be taken into account during the classroom activites and interchanges.

The aims of the teachers in using computer-based information packages fell into quite clear groupings:

1. Skills and Knowledge
2. Strategies
3. Socio-psychological Issues
4. Societal Issues

These four groupings were defined as follows:

1. What **skills and knowledge** do we want the children to acquire from this exercise? This was further subdivided into objectives related to cognitive development, communication skills and computing skills. For example, paraphrasing case study 9 (CS9), a cognitive intent would be to use data-bases to encourage the shaping of hypotheses and the formulation of questions. A communications intent would be to enable children to develop new and alternative ways of presenting information (CS6). While in CS16, the teacher specified the intent of developing children's keyboard skills; a computing skills objective.

2. What **teaching and learning strategies** will be employed?
There were four intents expressed here: to encourage discovery or enquiry learning; to

emancipate the learner by reducing the amount of inauthentic labour required of the individual; to operate an integrated studies approach to learning; and, to motivate the learner through the use of the computer. Kemmis, Atkin and Wright (1977) defined discovery learning as a gradual unveiling, during the learning operation, of key concepts in which content and related theory are progressively revealed. At first sight, more important to the type of work undertaken here is conjectural learning, in which the pupils learn through their experiences, experimenting and exploring an idea or topic. It is apparent from the teachers' comments that they were not using the term 'discovery' in this precise way, but rather it represented a very general statement of the children as active learners.

3. Influencing **the social and psychological climate** of the classroom.

The intents expressed under this category stem directly from the types of teaching and learning strategies to be employed and the nature of learning that the teachers felt could be stimulated by the use of the computer. Teachers expressed a desire to change the nature of classroom interaction (CS14) and to raise the child's self-esteem.

4. Children, information processing and **society**.

This final grouping of intents is less coherent than the the previous three groupings. In this teachers expressed intents which generally had a societal dimension. The first objective was to develop skills for life, the vocational objective. A second was to make children aware of the ethical issues in data-base use.

The percentage of teachers expressing each of these intents is shown in Table 8.1. While it would be inappropriate to draw detailed conclusions from percentage scores drawn from this small sample, a number of points may be made about the overall placing of emphasis of the teachers' aims. Firstly, there is a strong emphasis on aims which articulate the 'what' and the 'how' of education, with a reduced emphasis on the socio-psychological impacts and societal issues emanating from the use of the computer-based packages. This is not surprising, because 'what' and 'how' questions are the 'bread and butter' issues of teaching, and even the experts, cited earlier in this chapter, emphasis such aims.

Table 8.1

Teacher intentions expressed as a percentage by type and age-range taught.

Type of intent	Age-Range Taught: Early primary	Late primary	Secondary and FE	All Teachers
no. of teachers	4	8	6	18
Skills and knowledge				
Cognitive	75	100	67	83
Communication	100	75	83	83
Computer*	13	19	17	17
Strategies				
Active learning	75	63	50	61
Emancipation	0	38	33	28
Integration	0	38	17	22
Motivation	0	0	17	6
Socio-psychological				
Classroom interaction	0	25	17	17
Self-esteem	25	0	0	6
Societal Issues				
Life skills	50	50	17	39
Ethics	25	0	0	6

* each case study contributed two scores to this variable.

Skills and Knowledge

Looking more closely at the skills and knowledge intents, it is apparent that most teachers, whatever the age of their pupils, recognised that information-handling has both a strong cognitive and communicative component. Terms such as hypothesis testing, relevant questioning, problem solving, decision making and organisational skills were used, to a greater or lesser extent, by virtually all the teachers. For example, CS2 (secondary) argued that the exploration of the data-base should be used to encourage independent thought, to stimulate speculation and to aid students to develop the skills of the research worker. Only one teacher, a secondary teacher of history (CS1), failed to designate the development of one or more of these skills as one of his own objectives.

The greater emphasis on communication, rather than cognitive skill, by the teachers of the youngest and oldest students, can be explained in terms of the activities undertaken by the students in these groups. In half of the secondary case studies the children were being asked to use a pre-constructed data-base. They were not actively involved in those key classificatory decisions required to structure a data-base. Their main task was to use the pre-digested knowledge. As we shall see, this does not prohibit intellectual thought but it does remove one opportunity for children to think conceptually about data. In the case of the youngest children although they were involved in collecting raw data, the four teachers generally made the necessary classificatory decisions, as they felt that their children had yet to develop the appropriate cognitive skills which would allow them to structure the data. Although this is a view supported by the work of Olver and Hornsby (1966) other workers are more sceptical of this simple stage theory (Donaldson, 1978; Bryant, 1974) and this will be discussed further under transactions and outcomes.

As Ellingham (1982) advocated, knowledge of the computer is seen as far less important than the development of cognitive and communication skills. Only one teacher directly specified the development of computing skills as important. CS16 (early primary) felt that it was important to encourage keyboard skills in seven year olds. While it may seem strange that keyboard skills should be singled out, as few U.K. primary teachers have expressed a need to teach typing skills, it is probably legitimate to surmise that this intent is comparable with the vocational intents expressed by a number of other teachers in the sample. These in turn may well be a reflection of parental perceptions of the value of computing skills. The need for children to be aware of the weaknesses as well as the strengths of the computer as information processor, were highlighted by 22% of the sample.

Strategies

Aims concerning classroom strategies largely reflect the cognitive and communicative aims outlined above. More than half of the teachers (61%), particularly in the primary schools, felt that the manipulation of data and the structuring and restructuring of knowledge were skills best learnt through active learning strategies. The main reason for using a data-base was, for CS15, that the children would be actively involved or, for CS3, that children would be able to sort out materials for their own needs, McClelland's (1972) individualisation of education.

In categorising these intents, it is apparent that differentiating between intents and judgements can be problematical, many of the aims carried implicit judgements, for example CS10 suggested that the activities ... would allow children to reason and draw conclusions in an environment of enquiry learning. There is little doubt, however, that his aim was to operate an active learning strategy in the classroom. In the light of such statements, Stake's (1980) initial categorisation of responses was reduced to intents, with or without judgements, and observations, which might also be implicit judgements. Three teachers articulated a desire to change the nature of classroom interaction. CS10 (late primary) wanted to foster pupil-pupil interaction, a view echoed by CS6 (secondary slow learners), who felt that in developing the data-base children should be encouraged to pass information directly from one to another. CS14 (late primary) thought it important for children to gain control over their own learning.

While active learning strategies were particularly favoured by the primary teachers, the use of the computer to reduce inauthentic labour (emancipation of the learner) was more likely to be expressed as an aim by workers with older children. Surprisingly perhaps, a direct reference to the motivational potential of the computer data-bases was expressed only once, by a teacher (CS3) of fourteen to sixteen year old craft students, although within the overall enquiry strategy, comments about 'ownership of data' and 'the collection of materials for their own use,' do suggest a covert appreciation of the motivational aspects.

Socio-psychological Issues

Overt socio-psychological intents were rare, only one teacher (CS17 - early primary) commented on the need to encourage the growth of self-esteem in the learner, although such intents were implicit in the decision to operate an active learning strategy. Although none of the teachers commented directly on their own role, the above intents suggested that didactic teaching would be discouraged, that the teacher's role would be one of classroom manager and facilitator in the learning situation, and they would no longer be the pivotal focus of the classroom. CS2 did comment that teachers should not over specify to children the required outcomes of their work because this would limit the children's own thinking, inhibiting novel solutions as children personalise new knowledge - a case of the teacher not being an inhibitor of the educational process. This approach belongs very firmly to the view of instruction in which the child develops by meeting and resolving uncertainty.

In contrast to the low teacher profile and clear encouragement of student independence, articulated in CS2, the teacher in CS13 commented that the uses of data-bases is limited only by the imagination of the teacher, a clear statement of who is in charge and where initiatives might be expected to come from!

Societal Issues

The emphasis on vocational intents by the primary teachers is both an expression of parental aspirations and, possibly, of a misguided view that exposure to the computer at a young age will automatically be beneficial in later life. The feelings here are among the most intensely expressed. CS13 suggested that in today's society it is vital to introduce children to the microcomputer as information store and information retriever; a real world skill (CS18)

CS6 stated that every opportunity should be taken to ensure that children are exposed to the functions of the computer, while CS17 stated categorically that it is the duty of every teacher to give all children the opportunity to handle information on a data-base, as they will need this skill in later life.

Only one teacher (CS18), working with six year olds, mentioned the need to raise the ethical issues of storing large bodies of information on computers. She argued that we should pose questions about who should have rights of access to the information stored in a data-base; who should be held responsible for recorded errors and, what problems might occur for the person whose data is incorrectly entered. The data protection act was not foremost in the other teachers minds. It should be noted that this intent could probably be re-classified as a transactional observation/ judgement in Stake's terms, for although it was specified as an aim it appears to have arisen out of the class project called 'Myself.'

A summary of teacher intents

The intents of this disparate group of teachers, using computer-based information-processing packages, were very similar. They saw an opportunity to stretch and develop their pupils' cognitive abilities and at the same time to encourage the development of important skills of communication. This was largely to be achieved by an active process of learning in an environment of enquiry. Children, working in this explorative classroom, would show benefits along the socio-psychological dimension as well as learning relevant life skills.

The emphasis in these intents clearly matched those aims and objectives articulated by educational writers in this area. This is not surprising: for example, Taylor and Maguire (1967) also found that teachers and educational experts substantially agreed on the educational objectives within high school biology. Stake (1970) has pointed out, however, that many teachers, through perceived ability or time constraints, feel unable to dictate priorities and quickily defer to the expert or text book writer, and it in may be that our teachers were largely restating expert opinion as their own intents in the classroom. In every classroom teachers have to make decisions about the allocation of scarce resources to each of several objectives. Teachers' priorities may appear different when measured against the educational outcomes of their classrooms.

Stake has further argued that the ordering of priorities (intents) may vary for any one individual (the teacher) depending on the way in which the individual is asked to express that priority. Although individuals may argue that a particular intent is of central importance, they may be unwilling to give a great deal of time to the pursuit of that particular objective. For example teachers asked to specify the principle aim of education, collectively considered the knowledge objective to be of most importance.

> "... Facing the knowledge explosion, the schools should help young men and women build skills --- and even discovering -- new knowledge" (Stake, 1970, Figure 2. pp.11b).

These same teachers were willing to assign no more staff time to the attainment of this objective than to the human/social or vocational objectives, and felt that in North America, vocational objectives regularly received priority over all other objectives.

The second part of this study will now analyse the transactions and outcomes of these classroom episodes, and consider the evidence of the extent to which the objectives expressed by the teachers were met and, in those cases where intents were ignored or not fufilled, consider why this ocurred.

8.2.5 An analysis of educational transactions and outcomes

The following analysis of the case study material uses the previously defined groupings of intents for the purpose of making comparative and critical comments. The nature of the data and the mode of collection prohibit the division of the classroom activities into transactions and outcomes. Many of the teachers' statements were both a comment on classroom pragmatics and a summative evaluation of the learning process. The first level of analysis consisted of accumulating evidence of whether recorded transactions or outcomes matched perceived intents. The percentage of teachers noting the occurrence of each type of transaction or outcome is shown in Table 8.2. It should be noted that in this first simplistic analysis no account is taken of the quality of the transaction or outcome.

Skills and Knowledge

Cognitive Skills

The majority of teachers were aware of events which could and did stimulate both the cognitive (72%) and communication(94%) skills of the pupils in their charge. Teachers and or pupils (roughly half the cases and mainly in the later primary age-range) were actively involved in providing the structure and form of data to be entered into to their data-bases. This task involved the use of classificatory and decision making skills.

Cognitive skills of data organisation: CS12, a data-base to highlight the level of road safety for pedestrians around a village school, showed clearly that the formation of a good research question could make the selection and organisation of data relatively easy. Initially the children began by focusing in on features important to road safety, such as the occurrence of zebra crossings. They quickly realised that an organisational structure which used such features as records and then used the criterion of place to designate fields, was not going to be effective. The spatial component, where a hazard occurred, was critical and in most instances they needed a place name to be returned as the meaningful answer. This led the children to restructure their data-base and enter data into place name records. Of course, this study clearly illustrated Papert's (1981) 'continuity principle' in action; crossing the road had meaning for these children, they knew what the goal was and it was, therefore, within their power to manipulate the material into an appropriate form.

Table 8.2
Teacher recorded transactions and outcomes expressed as a percentage by type and age-range taught

Type of intent	Early primary	Late primary	Secondary and FE	All Teachers	
no. of teachers	4	8	6	18	
Skills and knowledge					
Cognitive	50	100	50	72	(-)
Communication	50	100	83	83	
Computer	25	50	33	44	(++)
Strategies					
Active learning	100	100	100	100	(+++)
Emancipation	25	38	83	50	(++)
Integration	25	75	0	39	(+)
Motivation	75	63	50	61	(+++)
Socio-psychological					
Classroom interaction	75	88	83	83	(+++)
Self-esteem	25	25	17	22	(+)
Societal Issues					
Life skills	0	13	0	6	(—)
Ethics	25	0	0	6	

The difference between intents and outcomes for the total sample is denoted in the final column: (+) or (-) represents a difference of 10% to 19%; (++) or (--), 20% to 29%; (+++) or (---), 30% or +.

The activity of constructing a data-base does not necessarily develop good skills in selecting and organising information, however. CS14 illustrated both the teachers' and the children's inability to operate a consistent criterion for choice of items. In this data-base on transport, they designated Concorde as their example of a plane, a highly atypical category member, but specified an 'average family car' (typical category member) for the latter entry, when consistency demanded a Ferrari at least! (cf Rosch, 1975). It would appear that the teacher, or perhaps the children, was subverted by the glamour of Concorde into producing a data-base which would only confirm existing predjudices, such as 'flying is very fast but very expensive.' The lack of a clear, articulated goal for collecting the data on transport may, in part, explain the inconsistencies of data selection.

Even for files where the structure was pre-defined, however, the classificatory decisions often proved important. CS10 showed the potential for testing category boundaries that entry of data into such a structure could offer. Six children were working together to describe and identify a number of small animals that they had collected from an afternoon's field work. The teacher described the children's problem thus:

> Child1 "<u>immediately homed-in on the field which was giving her (and the others she was to discover) some difficulty. Stinging and biting was one feature of the creature about which she had not been able to make direct observations.</u>"

There then followed a discussion between the children as to what constituted 'stinging and biting.' Child2 decided that this attribute was a superordinate category attribute and that it could be used to separate animals from insects: the assumption being that this was a defining feature of the latter group. This type of erroneous classification, where an atypical concept (insect) tends to be either linked to the superodinate category by a pathway of concepts or, as here, to be misclassified, is quite common (Rosch, 1975; Schvaneveldt <u>et al</u>., 1985). Child3 argued that all creatures which could eat could also sting or bite. After a small prompt from the teacher, Child3 went on to note that the creature in question had a rear structure which looked very similar to a scorpion, and that it would therefore attack people.

Child4, was very reluctant to make a contribution to this discussion and continued to ask the teacher for the answer. The children, however, endeavoured to help her out of her difficulty. Child1 causally linked a negative response to having knowledge of the answer, to the answer itself, and suggested entering the answer 'no.' Child5, however, suggested that she look again at the creature.

The children had still not resolved the specific point of whether their creature was one which would sting or bite, nor had they resolved the global issue of what was meant by the field heading 'stinging or biting.' The children now began to explore these wider concepts and the teacher, after initiating the discussion, withdrew as he felt his presence would inhibit the discussion. Child3 adopted the role of leader and encouraged the other children to make a decision. Child1 now offered the argument that meat-eating and biting, in the attacking sense, were synonymous. This decision was taken up by the other pupils who now assumed that any insect with visible mouthparts would attack by biting and this would be the criterion on which they would base further replies. The property of stinging was now ignored by the children. Vurpillot (1976) has shown that children left to their own devices frequently fail to explore all aspects of a problem. It was some minutes later, when a different task was being undertaken, that Child5 commented that biting to eat plants was not what we would consider to be an attack, this insight was not taken up by the rest of the group, however. The teacher concluded that if the program had offered an option of passing over a field, all of the children would have taken it.

This exchange does of course exemplify a number of the other transactions and outcomes which will be discussed later but its inclusion here, demonstrates how even pre-formed categories can act as a stimulus to discussions on the structure of knowledge. The children were drawn into active decision making and operated a number of strategies to resolve the problem; these included solution by analogy (the scorpion) and by anatomical structures (the occurrence of mouth parts).

A final example of classification in action is taken from CS2, which uses an extensive teacher produced data-base on mammals of two island habitats. In this example the teacher overtly encouraged classificatory activity. Lower secondary children were presented with randomly produced lists of up to twenty animals from the data-base. The children's task was to first use the data-base to find the order and family of each mammal on the worksheet. The children were then encouraged to find the common features of mammals in each of the families. This was preliminary to third year work (13 - 14 year olds) which was designed to "to aid children in the formation of biological keys, binary trees which are used to sort mammals into groups in a coherent manner."

Cognitive skills of questioning: In this biological case study (CS2) it is apparent that children were being asked to question the data-base. This questioning of the data-base was seen as an important cognitive goal by the sample teachers, but not all questions act as a stimulus to the higher cognitive skills of hypothesising, seeking relationships and making connections, and in a very real sense reasoning about our world. The approach taken to questioning, who designs the questions, whether they are seeking facts or testing ideas, is of considerable importance in the assessment of the potential cognitive development of the children.

Farrar (1985), in her analysis of child /teacher discourse, has queried the ready ease with which questions are divided into factual recall and reasoning, and the assumption that the latter are in some way 'better.' She points out that it is no easy matter to define such questions and that there is frequently a confounding of variables, 'factual recall' is often confounded with 'cognitively simple,' and 'reasoning' with 'cognitively complex.' Moreover reasoning questions can be less useful than factual questions if they elicit a "don't know' response or ask for information concerning irrelevant detail.

It is in the nature of data-bases that all the questions asked had closure, such packages are driven by algorithms and they lack the heuristic structure for probabalistic reasoning necessary to begin to cope with open ended queries. Much of the work on the value of open ended questions stems from work on 'learning through discourse' (see Sigel and Saunders, 1979; and Wood, 1980) and is only peripherally relevant to this situation. The preponderence of closed questions does not mean that the questioning was at a low level, however. As can be seen from the example of CS2, on mammals, quite simple factual questions (Fact2) may be combined to answer complex theoretical questions, and the appearance of a large number of such questions does not necessarily imply a low level of thought is taking place.

Indeed the use of the simpler data-bases such as FACTFILE made it very difficult to ask complex, or highly specified questions and the children often found it necessary to split relationship or hypothesis-testing questions into component parts, and then to piece these answers together in order to resolve their initial query.

A classification of questions. It is with the above points in mind that a classification system was devised to aid in the analysis of the questions asked of the data-bases. These questions were grouped on the structure of the sort required to answer the query, and on the purpose of that query. The quality of questions, questions with a purpose, is also reflected in the information processing techniques (key communication skills) that the children operated. This produced a simple three-fold division with the latter two groups further subdivided into two and were defined as follows:

1. Page the data.

In this mode the child simply asks the computer to reproduce on the screen, or printer, specified blocks of the file with no manipulations. This is analoguous to opening a book at page 35 or 42, and often consisted of a complete record across all fields.

2. Fact seeking.

Here the machine is always used to manipulate the data but the type of questions can be sub-divided into:

Fact1 - list all the known examples of ..... These are simple sorts on one dimension and were used to list all the housewives or marsupials.

Fact2 - were identification questions, find the mammal, person, type of transport, which fits these properties. These questions generally explored two or three dimensions, but in certain cases were more specific.

Children could answer both of these fact seeking type of questions in the page mode, with the children manipulating the data themselves, of course, and this did happen in a few cases.

3. Relational

In these questions children were seeking relationships and patterns within the data through the testing of hyopotheses which could be either:

Covert, implied by the type of question asked.

Overt, a clearly articulated hypothesis.

Overarching research questions were often a feature of work which involved such questions.

The analysis of questions: The data in Table 8.3 provide a subjective judgement of the balance of question type asked in each of the eighteen case studies. In the light of the work of Olver and Hornsby (1966) and Piagetian theory, it was not surprising to find that the youngest children, case studies 15 to 18, were concerned with factual information retrieval and not with the testing of ideas. Two groups paged the data and never asked a specific question. CS18 commented that her six year olds were unable to formulate questions, but that they derived great pleasure from seeing their names and personal data on the screens. By seven the children were asking simple but logical questions, such as 'who has an elder brother?' (CS16), or identifying leaves using a pupil-constructed data-base on trees (CS17).

Table 8.3

The Occurrence of Three Types of Question in the Eighteen Case Studies

Legend

Occurrence of question type

this type of question was well represented

moderate use of this type of question

question type occurs but infrequently

a blank space indicates no occurrence of this question type

The above divisions are subjective, a proportional count was not possible for the following reasons:

1. There was a high variation in the numbers of questions recorded by the teachers. Some gave only exemplars, others inserted complete worksheets and full transcripts which gave great detail.

2. In studies, such as CS2 and CS10, the posing of global research questions were indicative not only of overt hypothesis testing, but also of the need to ask factual questions.

Grouping of Case Studies

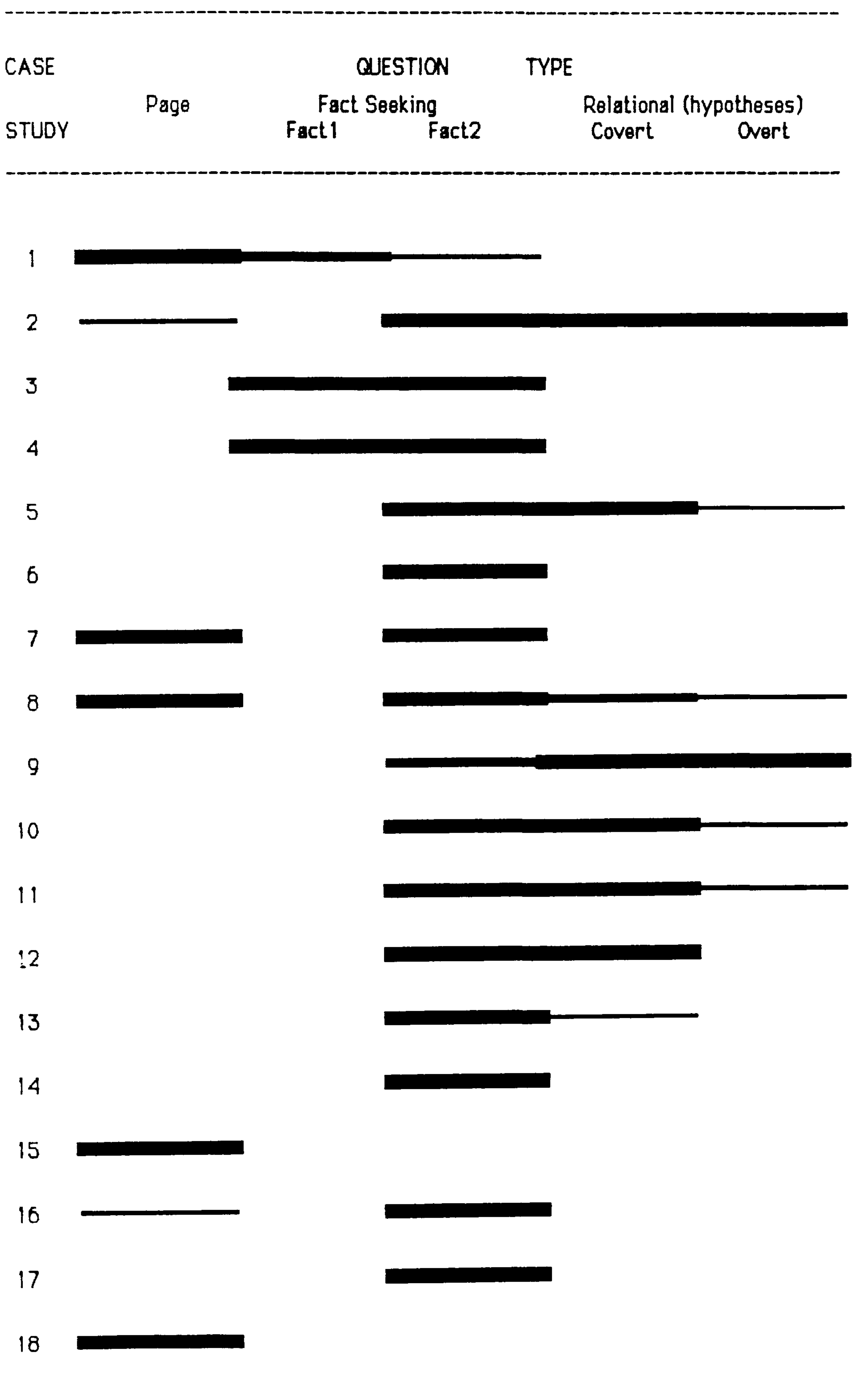
Case studies 1 to 6 -- secondary/ FE

Case studies 7 to 14 -- late primary

Case studies 15 to 18 -- early primary

Table 8.3

The Occurrence of the Three Types of Questions in the Eighteen Case Studies



It is worrying that the teachers of the youngest children should assume that questioning was beyond the children's capabilities. Donaldson's (1978) argument would be that the task had not been presented in a way that the children could understand. The structuralist models, such as those of Jean Piaget (see Flavell, 1963; Boden, 1979) can lead to teachers assuming limits to children's behaviour at any one time and thus to an unwillingness, due to the best of motives, of teachers to stretch children. Workers such as Donaldson (1978) and Bryant (1974) would argue underdeveloped language or memory skills might be the cause of what appears to be a failure in conceptual development, and that the simplification of instructions, particular with relevance to the child's own experiences, and *aide memoires* might produce quite high powered thought from children as young as the subjects discussed here.

In CS16, the teacher pointed out that the vagaries of the FACTFILE data-base caused many problems for the children. The simple 'who has an elder brother?' question produced a list of names each with a number denoting quantity of brothers to the right of it. The equally simple question 'who has a brother?,' was complicated by the structure of the data-base, for there were two fields relating to 'elder' and 'younger' brothers. The two questions were similar in syntactic and semantic terms, but the second question demanded a two field sort. Factfile again returned a relevant list of names, but the numerical data appeared odd to the children, for example Child1 was on the list but accorded no brothers. In fact the file had returned the last quantity requested only, the presence of one or more younger brothers, of which this child had none, but the child occurred on the list because she had an older brother. The children found this very difficult to grasp and decided to ask only one field questions in future and to piece their answers together from these building blocks.

In case studies 7 to 14, late primary, there was evidence of a questioning approach to the data. Although there was still some paging of the data, this now had a clear purpose, and the use of FACT2 questions occurred in all studies. More interestingly 75% of the studies showed evidence of the use of covert hypotheses and in 50% of the cases children were involved in testing clearly articulated premises as is shown in the following descriptions.

In CS10, a child was confused by a zero matching on a multi-field query, and re-ran the search to check the accuracy of the answer. The problem here, which was shared by the group as a whole, was coping with the counter-intuitive nature of the search. They felt that the more fields they specified the more records should be matched. They were unable to come to grips with the logic of a constraining 'and.' The children, with considerable help from the teacher, learnt to operate a two-field sort successfully but showed that they had not fully come to grips with the the concept of class inclusion/ exclusion by their failure to reach an understanding of the more constraining questions.

The teacher articulated the problem as one of the children making semantic associations connecting 'and' with mathematical terms such as 'summation' and 'adding,' each of which imply an increase in the final result. This might be described in terms of the Whorfian phenomenon (Slobin, 1979). The linguistic and logical meanings of 'and' are different, however, and these children were reaching to understand complex issues. The problem here is that the pragmatics of everyday life do not help us come to terms with the logical 'and,' and as a result this is a situation in which the 'continuity principle' cannot operate.

In CS9, the teacher successfully tackled the problem of class inclusion and exclusion by using a knitting needle for a hand-sort on a binary-selection punched card data store. Her aim was to aid her children's understanding of the nature of a computer sort before they used a machine-stored data-base, and, although the teacher did not articulate this intent, she was also to confront the children with the logical 'and.' The principle of such a sorting procedure is that a knitting needle is placed through the hole marking the attribute that is to be retained, for example 'girls,' and all the cards not pierced by the needle fall off, leaving cards representing 'girls' on the needle.

Her children had had some initial difficulty in answering the query "which boys had bikes" [boys and bikes = true]. The child conducting the sort had great difficult in understanding why when he put one needle through boys and another through bikes, he retained not only all the cards of boys with bikes but those without bikes and the cards of girl cyclists too. This is the reverse of the sort problem outlined by CS10, here the children were expecting a reduced number of cards with increased specification of the question, but the nature of the sort resulted in the inclusion of more records than expected. The problem was finally resolved when the children came to appreciate that they should sort on one field at a time, either boys or bikes, or vice versa, first. Through this the children came to realise the equivalence of 'boys with bikes' and 'bikes with boys,' the reversability of class. The teacher in this case reinforced the learning by enacting out the problem, grouping the appropriate children (boys with bikes, girls with bikes etc.) around the classroom. The children then transformed this knowledge into a Venn diagram.

The children now wanted to identify all the girls with watches and pets using two passes through the data only. However hard they tried, their simple binary sort resulted in a loss of data, either some of the girls with pets or with watches were dropped out of the sort. A prompt by the teacher to look at the cards which had fallen off the needle and to remember the equivalence of 'boys and bikes' and 'bikes and boys,' led the children to try a sort in the order pets, boys and then watches but this too failed. After further inspection of the discarded cards, one little boy had what can be described as an 'Aha' experience. He carefully explained to the rest of the group the importance of the order of sorting.

"<u>If you have watches and pets first then those that drop off we don't want at all, that just leaves the people with watches and pets. It's easy then to split those into boys and girls. Hey ... we can use either hole. We don't need a hole for boys and girls do we, because if you're not a girl you</u>

<u>must be a boy</u>."

He had come to terms with two problems simultaneously, the understanding of the concept of the logical 'and' plus a procedure for operationalisation of a search procedure to realise it.

These eight year olds were indulging in thinking similar to that required by the Wason and Johnson-Laird (1972) 'Four Card Problem,' in the sense that it was important for the children to come to grips with the nature of the discarded information, the not watches, not pets, and not girls. 'Not' here is used in Bateson's first sense highlighting the class of watches (see chapter 5). The teacher noted, however, that despite lengthy discussions of negative questions, no child posed such a question during the lengthy period of this work. Again the children were faced with a situation in which everyday pragmatic use of the language did not coincide with specialist use required for data sorting. The natural choice is to use negatives to falsify presuppositions and assertions but in such situations as here the function of the negative is to verify. Wason (1965) in his discussion of 'the context of plausible denial' has shown how reluctant individuals are to use the negative in this way.

These insights, however, were crucial to the successful use of the computer data-base. In posing the question 'Are the boys better swimmers than the girls?,' the children ran into problems resulting from the structure of the FACTFILE data-base. They initially wanted to identify all swimmers before operating a 'goodness' criterion to their sort, but this is no easy matter with FACTFILE (see Underwood, 1985) and it required an application of knowledge from the previous needle and punched card work, for one little girl to offer the solution of asking the computer to identify all the swimmers who could swim 0 (zero) metres, that is a negative question to ascertain all the swimmers regardless of distance.

Of course the use of multi-field sorts does not necessarily mean that thought provoking questions were being asked. The teacher involved in CS8, commented on the ease with which his eight year old children were able to cope with highly constrained questions. He, however, doubted the value of queries such as 'How many children have birthdays in June, blond hair, blue eyes, a height more than 130cm, and take a size 2 shoe?' The children were simply playing a game with the computer by testing its ability to hold all the variables in 'its mind,' a task they themselves would find extremely difficult, and were operating an hypothesis-scanning strategy, with no clearly defined cognitive goal or outcome. They were, however, gaining considerable expertise in information retrieval, and it has already been shown that without this skill many cognitive outcomes can be stifled.

As for the youngest children (e.g. CS16), coming to terms with the structure of the data-base and the format in which questions must be posed was problematic, but it did lead to valuable cognitive outcomes in those studies where the children were receptive and the teacher was aware of the problem. The examples, drawn from CS9 and CS10, clearly illustrate Donaldson's (1978) thesis that schooling is necessary to encourage special ways of thinking about and operating on the world. Her argument is that certain varieties of human reasoning, particular those necessary for the solution of abstract or hypothetical problems, can only come from 'schooling.' Appeals to common sense or plausible inferences are not enough, the child needs to understand the formal structure of the problem.

One last point from this age-range: it has already been noted that there is widespread acceptance of the principle of starting from the child's own knowledge and interest in order to maximise learning: the 'continuity principle' found in most theories of developmental learning. There are times when self-interest can be inhibiting, however. In CS10, one little girl involved in a social survey of her village, was very eager to question the data-base. With great enthusiam she asked the computer to identify all the village people who wanted to start a tennis club. The answer "none" was totally unacceptable, for she herself was a very keen player. She refused to have any more to do with the project since her own interests could not be met.

In case studies 1 to 6, secondary/FE, there was a strong emphasis on factual questions and only two studies (CS2 and CS5) showed evidence of rule testing and of questions which explored relationships. In part, this failure to achieve one of the key aims for using data-bases identified by both the experts and the teachers themselves, was due to the purpose to which the programs were put. In three of the studies (CS3, CS4 and CS5) the programs were used as reference texts to identify specific materials, careers or books, given a set of constraints. This, of course, is the most frequent use of information packages in the adult world, and while it gives little opportunity for the direct development of cognition, it does require skilled information retrieval and, as has already been shown, such questions can present the user with conceptual problems which require a solution before data can be accessed.

It is interesting to surmise, however, that the better the retrieval facilities of the software the less likely the user is to be faced with these cognitive experiences. For example, in CS4, the overall goal of allowing adolescents to match their interests, aspirations and qualifications to a potential career, would be better served by an expert system rather than a data-base. An expert system includes not only a data bank containing a series of production rules, but in addition an interpreter which determines how the data-base should be interrogated, allowing the system to make ostensibly intelligent decisions and to answer queries related to its specific knowledge base. To the user, the difference between an expert system and a data-base is that the former asks the questions, as a doctor questions his patient, in order to resolve the query in the user's mind. In a data-base, as we have seen, the user has to pose the questions, but it is here that much of the more fruitful cognitive activity occurs, and while the adolescents in CS5 would have resolved their careers' queries far more quickly using an expert system theirs would have been a very passive role.

The three investigative studies (CS1, CS2 and CS3) were each extremely interesting. In CS2, the teacher developed a spiral curriculum from first to sixth form, each with its own research problems on speciation in mammals. This study has already been referred to under issues in classification, but perhaps one additional comment will suffice. The teacher offered global research questions to each of his third and sixth forms, rather than more specific queries. For example, his sixth form were asked to identify and account for species variation in any one genus. A number of subordinate questions needed to be posed to resolve this problem, but the teacher felt that it was critical that the pupils constructed those questions themselves. Over-specification of questions, he suggested, would produce clones who thought only as the teacher thought and who would learn nothing about the process of generating hypotheses. It was important that children came to recognise the multiple routes to the solution of any problem and to value their own approach, where it was effective. Many educational thinkers would concur with this view on the grounds that self-constructed knowledge is more memorable and easier to make generalisations from, than given knowledge (cf Dewey, 1933; Piaget, 1952; Bruner, 1966; Papert, 1981). Einstein (1957) in raising the problems which result from the use of pre-digested ideas and concepts in scientific enquiry, offers a pragmatic justification for encouraging novel thought patterns.

> "In the attempt to achieve a conceptual formulation of the confusingly immense body of observational data, the scientist makes use of a whole arsenal of concepts which he imbibed practically with his mother's milk;........He uses... these conceptual tools of thought, as something obviously immutable given; something having an objective value of truth which is hardly ever...to be doubted....And yet in the interests of science it is necessary over and over again to engage in the critique of these fundamental concepts, in order that we may not unconsciously be ruled by them. This becomes evident especially in those situations involving development of ideas in which consistent use of the traditional fundamental concepts leads us to paradoxes difficult to resolve."
>
> (pp. xi-xii).

Miller (1973) takes this argument further, it is not sufficient to question the conceptual base, this questioning must have an element of play. He argues that while exploration transforms the novel into the familiar by allowing the construction of general statements, play transforms the familiar into the novel. All theories result in a selective acceptance of data, which governs that which we see as relevant and that which we describe as 'noise.' Inevitably play is involved in this process because we must pretend some things are important and some are not. Thus for Miller, the reinterpretation of reality or the production of novelty occurs through play and this results in flexible thinkers able to deal with the changing world.

Science, then, will not flourish without the continued testing of our fundamental conceptual base and this testing must be in an active learning framework.

In CS5, children produced a data-base with the aim of identifying the nature and causes of dental problems within adolescent children, namely themselves. As can be seen from Table 8.3, their questions were both factual and relational. One of the important points of this study was the way in which children re-formulated questions following output from the data-base. For example, the children felt that brushing teeth twice a day would lead to an improvement in health, that is fewer fillings, extractions and bleeding gums. They were surprised to find that the evidence did not support this hypothesis but still felt that their initial assumption was valid. The hypothesis was therefore modified to explore the effects of not two but one cleaning per day and this indeed was correlated to dental health.

In CS1 the children did not question the data-base they simple paged through the material and extracted the data by 'eye.'

Cognitive outcomes were, therefore, most apparent in the late primary studies. The youngest children had not developed the conceptual base from which a systematic enquiry approach could be built, nor were they aided to construct one. In the secondary/FE sector skills of enquiry were often highly developed but the use of data-bases with these older pupils was often restricted to reference seeking rather than an exploration of ideas.

Communication Skills

The transactions and outcomes involving communication skills occurred as frequently or more frequently as cognitive outcomes across the age-ranges, and were particularly important in the late primary (8-11 years) case studies. The types of communication skills encouraged throughout these studies fell into two broad categories: those involved with information processing on the computer, for example encoding of data and information retrieval; and, those skills involved in the collation and presentation of data off the computer, including questionnaire design and the transformation of data from one medium to another.

In all but three of the case studies, CS1, CS15 and CS18, there was evidence of a growth of computer-based information processing skills. Even in these latter two studies, working with the very youngest children, the children did learn to page through the data-base. In the secondary case study, CS1, the teacher's attitude to the usefulness of the computer data-base was summed up in his assertion that, "Much of the analysis could be performed with the printout itself without needing the investigatory properties of the programs at all." This was despite the initial assertion that the computer brought limitless flexibility and emancipation to the classroom. This does not negate the fact that the children were involved in information processing skills, but the involvement was through manual sorts when it took place, and the majority of the work appeared to be by individual case studies, with little reference to collective data or to the development of general statements or laws. This teacher was preoccupied with a major problem for teachers who try to involve their children in historical research, that problem is the illegibility of documentory evidence. The teacher was obviously so pleased to have a printout that the children could make sense of, that the he failed to see the benefits of a computer sort, legibility was his primary goal.

CS7, exemplifies the problem of making inferences from case study data. In this example the children were very much in charge from the beginning of the project and having constructed their file they then wanted to see it used by a parallel class. There followed an animated discussion on the best way to introduce the second class to the file, the outcome of which was two question sheets. The first sheet required the children to page through the FACTFILE, while the second sheet contained more constrained questions, which were to be answered using the sort routines. The 'teacher-children' argued that paging would give a feel of its structure to those children who had not been involved in constructing the data-base, a necessary precursor before moving on to more complex interactions with the file.

Although at first sight the second set of questions, all of which fell into the FACT2 (identify) type, was ostensibly geared to helping the children understand more about European countries, they were in fact constructed in such a way as to provide a stepped learning sequence through the information retrieval skills required to use the file. Questioning in this case had little to do with hypothesis testing, it was a means of interacting with the file and produced benefits largely in communication rather than cognitive skills, although such skills may have been enhanced by the act of teaching in the 'child-teachers.'

It is apparent from many of the examples already discussed that it is extremely difficult to separate the development of cognitive skills from the development of communication skills. Indeed, some would argue (Bruner, 1966; Vygotsky, 1978) that it is undesirable to try to do so for the representation of knowledge is the essence of thinking.When asking questions children have to take cognisance of the data structure and develop skills in using the data-base, but in coming to terms with the specific demands of their information package, the children may be forced to think counter-intuitively (CS10) or to gain new insights into basic concepts such as equivalence (CS9).

Similarly, in seeking cognitive ends, children may be forced into new ways of representing data. In CS12, the children were conducting a road safety project and their clear goal was to identify accident black spots and safe places to cross the road. Their first attempt at retrieving the required information from the file was not successful, the nature of the data format inhibited access to the information the children knew to be in the file. They had used lengthy string, rather than numeric, descriptors for most fields, but the children came to appreciate the need for numeric coding after several fruitless attempts to access the data-base. For example, in categorising certain road junctions close to their school as heavily used or not, they employed a five point scale; 1 represented a junction with low flow and no commercial traffic and 5, a junction with lots of heavy commercial vehicles. These children made an important breakthrough in their understanding of the way in which data-bases and computers can be used efficiently. In the latter case they came to appreciate that the computer could be used with other tools, in this case work sheets displaying a full explanation of each field's structure. Secondly, they learnt that you often have to re-present data to pick out essential patterns, and that this might involve putting the data into a different form, collapsing the data and even throwing away material.

These children clearly demonstrated communication skills by producing a hazard map of the area around their school which was a synthesis of the information stored in their data-base. This transformation of data from one medium (data-base code) to another (spatial representation) in order to project a message, is at the heart of communication. Skills in information processing were clearly shown in the majority of case studies. For example in CS2 the pupils were encouraged to produce species distribution maps. In CS5, CS8, CS9, CS10 and CS11 data was transformed into wall charts, pictograms, graphs and venn diagrams; each with the goal of further elucidating the data. In CS13 the children used their factual data on the solar system to create images of the planets and the imaginary life that could exist there. Here art and the collation of scientific fact came together to support the act of design.

The potential of this work was rather greater than the final outcome as the teacher did not encourage the children to go that little bit further in articulating why each feature of their monster would be an important adaption in each particular climate.

In those case studies (CS3, CS4, CS6 and CS17) where the data-base was used as a reference text, the mode of use precluded such reworking of the data. Again CS1, CS15 and CS18 responded differently from the majority, the latter two because the students were deemed too young by their teachers, and the former, because the teacher did not appear to encourage such transactions and outcomes.

Computer Related Skills

Transactions and outcomes related to the development of computer skills were recorded less frequently than cognitive or communication outcomes. In CS15 the children discovered errors in their data-base. This made them aware of the need to check all inputs and of the literalness of the machine; it works with the data provided and it is only as good as the information fed into it. One sophisticated insight was offered by a more able eight year old child (CS8), who recognised the problem of drawing conclusions from a small data-base (32 subjects). He felt that the data-base could be easily expanded, with the aid of the computer's memory, in order to allow more valid conclusions to be drawn. The children in this study also remarked on the way in which the computer would present answer lists in different orders depending on the nature of the question; for example, the names of children with birthdays in June were presented alphabetically, but a similar list of children by weight or height would be sorted along the numeric dimension. The children thought this very clever of the computer and it also presented the teacher with a stimulus point from which to discuss issues in communication.

Of course such stimuli can be abused. In CS10 the teacher dazzled the children with the computer's statistical powers. It was apparent, however, that although the children were impressed by the computer's ability to produce frequency counts and the like, there was little understanding of what the results meant or indeed what the computer was actually doing. This transaction appeared to be directed towards a goal of enhancing the computer's reputation in the eyes of the children. The teacher's notes on this transaction suggested that he was also entranced by the computer's powers.

The majority of transactions and outcomes were, however, related to the efficient use of the machine. In CS11 and CS5 the children learnt to make back-up discs after each session in order to limit any damage that might occur from a hardware failure or a user error. While the teacher in CS2 produced a user document of 'do's' and 'don'ts' when using a computer.

It was generally apparent, however, that the computing skills were being seen as precursors to more interesting and important activities and knowledge. The greater emphasis on such skills in the middle age-range can yet again be explained by the high teacher-input with the very young and the use of the data-base as a reference text in half of the older age-range studies.

Strategies

<u>Active learning and emancipation</u>: In all the studies, teachers presented evidence of active learning, to a greater or lesser degree. In those studies using the computer package as a reference text this was limited to searching the data-base for a specific list of 'ingredients.' The children were none the less involved in goal-directed behaviour and were required to devise the structure of their sort. In all such studies the emancipatory role of the computer was noted and the preponderence of this mode of use in the secondary/FE age range explains the greater frequency, in these case studies, of transactional judgements relating to that role. In this age range, studies (CS2 and CS5) which used the packages exploratively also noted

transactions and outcomes, often judgemental, related to this removal of inauthentic work from the child. This was almost certainly a result of the size of the data-bases constructed which tended to be very much more extensive than those used by the primary groups.

Integration: No case study in the secondary/FE age range presented evidence of an integrated approach to the curriculum. This is not surprising, it is not in the nature of secondary schools to cross discipline bounderies. Integration was most apparent in the late primary age range where a topic approach to the curriculum is the norm. Here children were encouraged to link mathematical and scientific studies to the creative arts. For example, in CS13 children produced descriptions and sketches of imaginary creatures who might live in the very real planetary conditions of our solar system.

Socio-psychological transactions and outcomes

Motivation and self-esteem: When describing their intents at the beginning of these studies, teachers expressed motivation in strategy terms, that is the teachers saw the use of the computer as a teaching approach. In analysing the transactions and outcomes of these studies, it is apparent that motivational statements were now closely related to socio-psychological outcomes. They were expressed in terms of the children and their self-perception rather than in terms of a way in which the teacher could pass on valued skills and knowledge. Reference to motivation occured at all age levels but also increased with decreasing age of the children. In CS15 and CS18, the teachers both commented on the thrill the children received on seeing their own names on the screen and indeed, CS15 recorded problems of management because of the over-stimulation of the children. In CS5 and CS7, the children were excited by the prospect of producing their own data-base. Motivation here was due to the sense of positive power which comes from the ownership of a skill or a block of knowledge and is very closely aligned to self-esteem. In the former study a high level of motivation was essential for the successful completion of the task. In this school computing facilities were particularly poor and this made it necessary for the children to input data to the machine in any and every free moment they had. That children were willing to work unsupervised over lunch-times or before and after school to great effect is indicative both of the spirit and self-discipline these children brought to the project.

Only a handful of cases, spread across the age-ranges, mentioned self-esteem specifically. In CS3, the teacher commented on the feeling of adulthood that using the data-base gave to his students, partly, in his judgement, because they felt they were in control and the teacher was not there to assess their attempts to acquire desired knowledge, but also because use of the computer was perceived as an adult act. Acquired status from using the computer can be a stimulant to learning. For example, basic skills programs have been used effectively with language retarded adolescents because they felt that the computer was for men, and not kids' stuff.

Classroom interactions

The majority of teachers at all levels commented on the interactions between pupil, teacher and machine (Table 8.2). It is apparent from the previous discussion, however, that although the specification of intents was relatively simple, statements of transactions and outcomes do not fall easily into the neat headings of Table 8.2. Much of the evidence of active learning, motivation and self-esteem, and indeed the role of the teacher comes from an analysis of classroom interactions.

Play versus work: In CS15, the children used the data-base under two sets of conditions, either as a group or in a one to one relationship of child, computer and adult helper. The enthusiasm noted by the teacher under the first regime evaporated in the second situation. The teacher commented that her young charges required the stimulation and interest of the other children to maintain their own interest. Activities with the adult were seen as work and of little value. Chandler (1984) argues that teachers habitually make distictions between 'play' and 'real work,' and it would appear that these five and six year olds had already learnt that distinction.

This is an unfortunate division which arises partly out of theories of play, but also from our cultural respose to the words 'work' and 'play.' Schwartzman (1978) states that most theories of play agree that it is pleasurable and enjoyable experience, characterised by freedom and spontaneity and requiring the active participation of the individual. It is generally assumed to be unproductive and without 'real' consequences for life: for example Garvey (1977) argues that play has no extrinsic goals, and occurs separately, in time and space, from other non-play activities. As Chandler says, with such a definition it is hardly surprising that play cannot survive in the school curriculum.

Schwartzman argues, however, that while the pleasurable aspects of play need not be questionned, it is not at all clear that play is unproductive and without goals. Miller's (1973) argument on the central importance of play in theory construction has already been discussed, and Schwartzman provides further evidence of the relevance of play in creative thought and in the advancement of science (see pp.328). She concludes from her extensive review of anthropological studies, that play itself encourages those vital skills of re-interpretation that lie at the heart of cognitive development.

> "Children at play learn how to be sensitive to the effects of context and the importance of relationships; they develop the capacity to adopt an 'as if' set towards objects, actions, persons and situations; and they continually explore the possibilities of interpretation and reinterpretation and with this the creation of new possibilities." (Schwartzman,1978; p. 328)

In study CS15, one set of interactions were described as play because they were enjoyable and the children were active participants, but in the adult-child situation the activity was no longer fun and the children took a far more passive role, therefore this was work. It was in the first situation that the children were motivated to discuss their data and to ask questions about the computer, and to come to an understanding of the important principle of reciprocity. Each child wanted to show the others his or her personal data, but this involved both taking turns and showing an interest in other people's data. This they achieved with little difficulty.

The comments from this study raise a number of educational issues: one is the deep prejudice against play in the classroom which is understood and accepted by even very young children, as here; a second is the assumption that work cannot be fun; and, thirdly that play cannot have extrinsic goals. If, however, we accept Schwartzman's thesis that play is essential for creativity, occurring in all aspects of our lives, and is therefore of pivotal concern in the classroom, then there are a number of classroom benefits. The reluctance to stimulate such peer group interactions, as noted in CS15, will be diminished, if not removed altogether for the non-compatability of play and the curriculum noted by Chandler will no longer hold true. Equally teachers will be able to use that considerable motivating power of play to educational ends.

In a number of studies there was a gradual shift in the nature of interactions as the project continued. In both CS10 and CS13, the teachers were very actively involved in teaching about the computer and about using the data-base at the outset of the project, but there was a gradual reduction of this didactic role as the children's skills increased. In CS13 the teacher commented on his changing role from authority figure to facilitator as the children grasped the elements of 'computer speak.' By the third session with the machine, the teacher in CS10 was operating a deliberate policy of withdrawal to allow the children to discuss and make decisions without him. This did not mean that the teacher negated his responsibilities rather that he saw, and clearly demonstrated, his role as catalyst at critical points in the project. "<u>I withdrew at this point in order not to inhibit the discussions taking place between the</u>

children." In discussing cognitive and communication outcomes, it has already been shown that the children in this study took on a variety of new roles, carefully leading a weak member of the group to a decision point and, in one case, taking over as the authority figure in the group. This key role of teacher as facilitator is also well demonstrated in CS9, both in earlier discussions and in the following transcript (CS9).

Peer group facilitation: To discuss interactions in terms of the interactions between teacher and pupil over simplifies the wealth of relationships that have been established in these studies. One of the more encouraging outcomes is the willingness, and the competence, of children to take on roles of responsibility, caring and sharing. In CS7 the production of a programme of work by one class for another has already been discussed. Interestingly, the teacher adjudged here that, in teaching their peers, the children came to a better understanding of the material in question and actually retained factual knowledge that had been excluded from the data-base. She argued that, of three parallel classes, only those not involved with the computer, as either teachers or pupils, developed negative attitudes to the project as a whole. The two computer user groups retained sufficient enthusiasm to search the library for further information once the official project was over.

There is an extensive literature supporting these conclusions of peer facilitation in learning. Much of this work arose out of the claims of rival learning theorists,' for example Piaget has argued that conflict and confrontation between children's differing viewpoints would be a powerful stimulus to intellectual development. Vygotsky (1962) concurs, stating that the child moves from pre-scientific thinking, epitomised by the inconsistency of concepts, to a more stable perception of reality through the resolution of competing predictions. This does not imply the strong maturational link inherent in the Piagetian viewpoint, however. Wood (1980) points out that this need for children to experience conceptual conflict is also found in the disparate theories of Isaacs, Dewey and in Bruner and his colleagues.

Doise, Mugny and Perret-Clermont (1975; 1976) have shown that children working in pairs on Piagetian conservation tasks perform better than equally-able peers working alone, and that this superiority carries over into performances of individuals in the post-test situation. Similar findings are reported by Glachan and Light (1982) and Light and Glachan (1985) who asked eight year old children to resolve the Tower of Hanoi problem.

They comment on two additional findings, however. Children who had worked in pairs not only performed better in the post-test situation, there was also a qualitative difference in their performance, in that they showed a greater ability to generalise their new understanding to other problems. This is the 'golden fleece' all teachers say they are looking for, transferability of skills. They also noted, however, that these beneficial effects were not shown by children who lacked any strategic approach to the problem at the outset, nor where one child was allowed to dominate the activity to the exclusion of his or her partner. Foot and Light (1984) replicated these results for children working on problems with the microcomputer. They found a further interesting limitation to the result, if children were highly involved with the keyboard, rapidly typing in answers, then there was no learning facilitation. If the children's key pressing was slowed either by an additional pencil and paper task or by insisting on dual control of the keyboard then facilitation occurred.

Other examples of children acting as experts, passing their knowledge on to their peers, or even setting up a store of information for other pupils to use and extend at a later date, are found in CS6, CS8, CS12 and CS17. In the latter case two children developed a tree identification program to be used by the rest of the class and they carefully drew up a users' document which included explanatory sheets on terms such as bud and leaf arrangement.

<u>Dynamic interactions</u>: The most invigorating observation that arises out of these studies is the dynamic nature of the interactions in which the computer plays a full part. This is clearly

shown in the following transcript (CS9), which provides a fascinating exemplar of classroom interaction when a discovery learning strategy is encouraged by the teacher. It is a short play in three acts. There are five actors - three children (C1, C2 and C3), one teacher (T), and the computer (CBL). The play might be called 'Changes in the Locus of Educational Control' given that the events of particular interest involve the children, teacher and computer taking control of the interactions at different points. Just as Papert found that LOGO enables children to take control of their microworlds, this program encourages these eight year old children to question answers suggested by the computer, to 'teach' the computer to describe a new datum entry, and, perhaps most importantly, helps the children discover the importance of asking good questions.

The lesson is part of a botanical project on the identification of trees. This part of the transcript concerns the uses of leaves as identifiers. The teacher did not specify on what grounds the group was formed, but it did consist of two girls and a boy.

<u>Act 1</u>: With the Computer (Computer as authorative source)

CBL + C1:	Is the leaf just one simple leaf on a stalk? (C1 acts as computer operator throughout, reading aloud screen instructions, and entering responses via the keyboard).
C2:	What does "simple leaf" mean?
C1:	It means all in one piece and not in bits like a chestnut.
C2:	Oh, well it is then - press Y.
CBL + C1:	Has the leaf got an edge like the teeth of a saw?
C3:	My turn. Well it's got a curved edge but not like a saw.
C2:	Let's see - mmm, I agree.
C1:	OK, I'll put no.

CBL + C1: Has the leaf an oval shape and the veins going right to the edge?

C2: Neither.

CBL + C1: Has the leaf got prickles?

C3: No.

CBL + C1: Oak.

C2: Let's tell T.

C3: It doesn't look like an oak to me!

The sharing of keyboard activities and the careful agreement between the participants before entries are made into the computer shown here must be considered significant aspects of this interaction following the work of Foot and Light (1984) cited earlier.

Following the questioning attitude expressed by C3, T suggests further research in the library. Here the program acts as an initiator of other learning-related activities, and T is acting as a manager of the educational environment.

Act 2: In the Library

C3: Oak leaves have deep rounded lobes with two small lobes at the base. Our leaf doesn't. The ends are more pointed.

C2: In an oak leaf the top part is wider than the bottom - ours is the other way around.

C1: I think I've found it. Is it a maple leaf? It says that the leaf and veins have milky stuff in them, and this one does.

Act 3: Back with the Computer (The children teach the computer)

The children confirm their finding with T and enter a new leaf in the SEEK data-base. Still operating in the "identification mode" which they were using in Act 1, they again get to the point where the program tells them that they have an oak leaf ...

CBL + C1: Oak.

C1: No! Oh, what's happening? (The screen display is changing at this point.) It's disappearing. Wait, part of it's still on. It says "What is it?"

T: It's asking what the leaf is if it isn't an oak.

C1: Oh, silly me. Right, let's put in maple. M-A-P-L-E.

CBL: A question to give the difference?

T: It wants you to tell it a question to show the difference between the two leaves.

C2: Is the top wider than the bottom?

C3: Does it have two small lobes at the base?

C1: Does it have milky stuff?

T: Which one do you want to use? Remember that it must have a YES/NO answer.

C3: Use Jackie's (C2) - it's the clearest.

C1: What do you mean?

C3: Well, it's the easiest for anyone to see when they look at it.

All three children are actively involved in devising and evaluating questions. Their final choice is based on ease of use. It is interesting to see that the children were able to reject the question concerning the milky fluid, an exciting characteristic of the maple, for the duller but more pragmatic question on leaf shape. This is no easy matter as was apparent from the inappropriate inclusion of Concorde, as the example of air transport in CS14.

In selecting the most appropriate question these eight year olds are showing both an ability to shift perspective and to make judgements about those various perspectives. In Piagetian terms the children have progressed towards 'decentring' operational judgements. While children's thinking at this age might be expected to be in terms of 'pre-operational centrations,' Piaget does allow that experience of conflicting ideas can accelerate the move to operational thought and Doise et al. (1975; 1976) have shown that peer group learning does facilitate 'decentring.'

C1: OK, shall I type it in?

C2 + C3: Yes.

The children then entered their newly found defining characteristic and new datum, and worked through the program to check that they could identify a maple leaf.

Not all interactions with the computer will be of this quality but there is now enough evidence to show that the computer in the classroom can stimulate worthwhile educational outcomes, and this exchange illustrated a number of those desirable outcomes. A questioning attitude was apparent, with no straightforward acceptance of machine-produced solutions and a marked appearance of both child autonomy and group cohesion; the children appeared to be teaching one another, partly by teaching the computer; the teacher had a managerial/facilitator role in that she no longer provided final answers but pathways to answers for the children to explore themselves.

In this transcript and in other discussions, such as that on 'biting and stinging' from CS10, there was evidence of the teacher stimulating the children to take an active part in the discourse. This was achieved in a number of ways; for example, by the use of 'distancing' questions (Sigel and Saunders, 1979) or by offering suggestions or speculations congruent to the context of the study (Wood and Wood, 1983). All enquiry structured lessons have this potential, but it is because the use of information processing packages stimulates inquiry-type activities that the opportunity for these beneficial aspects of discourse can be encouraged.

These interactions, and those highlighted from other studies, clearly show that children had an opportunity to take on new roles and responsibilities as Bradshaw (1985) has argued they should. He quotes a number of university departments who are actively involved in re-organising their teaching to encourage similar outcomes at the behest of employers. It can surely be argued that these activities fulfilled Papert's principle of 'cultural resonance.'

Perhaps the most encouraging development was the appearance of the children's questioning of their own questions - they came to understand what was a good question through evaluation. They have also come to realise that the 'goodness' of the question may vary with task it is to facilitate.

Societal Issues

On the whole societal transactions and outcomes were not recorded by the teachers. Only in CS15 were ethical considerations important and here the six year olds discussed who should have access to their data file. They also discussed who was at fault and who might suffer from an incorrect input of data. This discussion arose out of their own experiences of erroneous data input. These might appear rather high powered discussions for such little children but the disturbing fact that arises from these studies is that although many teachers, at all age levels, recorded data errors they saw this in terms of poor program structure, a hurdle to be surmounted. No other teacher recognised the underlying ethical issues.

8.2.6 A comparison of expressed intents and recorded transactions and outcomes

The similarity between expressed intents (Table 8.1) and recorded transactions and outcomes (Table 8.2), aggregated across the eighteen case studies, was analysed using the Spearman's Rank-Difference correlation. This test was chosen rather than the more exacting Pearson Product-Moment correlation on the basis of sample size (Meyers and Grossen, 1974). There was no consistent relationship between expressed intents and educational outcomes ($p=+0.54$; $df=10$; n.s.).

Quantification is not valuable in absolute terms, but only in as far as it provides a useful reduction in the data, in order to draw attention to trends and patterns. In this case the analysis raises the question of whether the differences in emphasis between intents, on the one hand, and transactions and outcomes, on the other, imply a critical difference between expressed goals and actual priorities in the classroom, or are we simply recording the fact that when operating in the classroom, it is the pragmatics of the situation which are foremost in the teacher's mind. This analysis raises the issue of the validity of frequency of occurence of any event as an index of importance versus the critical episode. In essence, however, because the data has been filtered through the teachers' own perceptions and educational priorities, the information discussed here is a frequency count of critical episodes, or points of significance as seen by those teachers.

To comment that teachers did not achieve what they set out to do would be too harsh a judgement. Teachers' initial focus of intents was on the skills and knowledge to be taught; while the development of life skills, the vocational purpose of education, was also highlighted. Not surprisingly in recording transactions and outcomes the teachers focussed to a far greater extent on the managment of the classroom, on how to organise the learning environment, and on the child, in particular the socio-psychological outcomes they could actively observe. It may be, however, that this result is inherent in the method of data collection, in that transactions and outcomes are likely to be selective (what catches the eye) while intents are all inclusive (a precis of what the 'experts' say). In such conditions, concerns such as time on task, motivation and co-operative endeavour are likely to be more dominant than long-term educational issues. With these caveats in mind, there are nevertheless a number of useful points which can be made from a comparison with intents.

In the area of skills and knowledge the majority of teachers (72%) were able to provide a learning environment in which their pupils developed and tested their cognitive skills but, this is one of only two areas in which recorded transactions and outcomes fell short of intents (83%). Only teachers in the late primary age-range matched cognitive outcomes to intents. The discrepancy noted in the other two age-ranges resulted from the reference use of the data-base with many of the older children and, the assumption that the youngest children would not be able to classify or ask questions of the data-base by teachers of the very youngest children.

Transactions and outcomes related to communication skills were matched to intents across the full sample of case studies. They were least important , however, for the youngest children for whom an adult often took on the role of information retriever. Although the emphasis in the transactions and outcomes was heavily weighted towards the cognitive and communcation skills, computing skills were prominent in the descriptions of classroom events. It was apparent from the reports that teachers felt that there was a basic level of computer skills and knowledge that children had to acquire before they could test the data-base but, as with such skills as holding a pencil or being able to read, these underpinning skills were not itemised in intents.

A greater emphasis on strategic outcomes, compared to intents, was generally apparent for the full sample. For example, all case studies recorded the use of an active learning strategy for at least part of the programme, although with the youngest pupils the children had fewer opportunities to guide their own work despite teachers of this age-range initially being the greatest supporters of this strategy of teaching. The importance of the active learning strategy lay in the opportunities it provided for a variety of classroom interactions and in the motivation of the children. As is shown in Table 8.2, it is the nature of such interactions (83%) which captured the attention of many of the teachers although they figured little in the articulation of intents (17%). The variety of roles taken up by both teacher and pupil and the shifts in locus of control were evidence of a dynamic social structure which often had important learning outcomes, as for example in CS2, CS5, CS9 and CS10.

The increased emphasis on the emancipatory role of the computer is a reflection of statements by the teachers of the oldest children, and is clearly due to the use of the computer as a reference source and to the generally larger banks of data used by these children.

Societal issues were rarely mentioned in the transactions and outcomes even when an opportunity presented itself. For example only one teacher dealt with the ethics of computer data-bases following an instance of incorrect data input. Many of the groups had similar experiences but no other teacher felt either the need or recognised the teaching point presented to them.

In describing intents at the beginning of this chapter it was stated that teachers concentrated first on the 'what' and then on the 'how' of education. In discussing transactions the 'how' now took precedence over the 'what' with increasing importance on the 'who.' Who controlled the learning experience, who was the decision maker, who would benefit from the experience? Vocational issues were of little significance to these teachers, even for the careers data-base transactions and outcomes were framed in terms of the benefits to the adolescent using it and not in terms of societal goals. Bradshaw (1985) would argue that this is exactly what employers want rather than the rather old-fashioned view of specific behavioural skills the teachers recorded in their intents.

In summary, teachers expressed a number of aims for their use of data-bases in the classroom, and these intents showed a collective knowledge of current educational thinking in the area. The recorded transactions and outcomes from the use of computer-based information-handling packages did not match intentions, however. The cause of this disparity appears to be the shift in focus of attention from global issues during the planning phase (specification of intentions) to the pragmatics of learning and classroom management, and the responses of individual children, during the action stage. In a number of cases there appeared to be some confusion over what should be classified as a cognitive outcome, and this reflected Chandler's (1984) concerns about information processing skills being seen as data manipulation rather than developing conceptual insights.

8.3 The Uses of Computer-based Information-Handling Packages in Schools

Kuhn (1961) has pointed out that measurement rarely leads to theory but on the contrary, qualitative theory development has usually preceded and often guided and inspired measurement. This is a timely warning for those wishing to use information-handling packages to stimulate cognitive development, for it suggests that a bottom-up approach, collecting baskets of data and manipulating them to see what drops out, is likely to be less effective than the top-down approach, where a specific research question is posed and data collected to support or question the initial assumptions. In the former case the emphasis is on valuable but lower level skills of data manipulation while in the latter case, the posing and testing of ideas, the questioning of concepts is highlighted. This split was apparent in those studies which used the information packages in an investigative programme. Although each specified cognitive intents, those operating a bottom-up approach were more likely to operate hypothesis scanning strategies , if they tested rules at all. Those studies which began by specifying clear research aims always operated a questioning approach in which a constraint strategy was evident.

This top-down approach which includes clear specification of goals and problems has a validity beyond the classroom, as does the mode of solving those problems through active participation in the learning experience (Bradshaw, 1985). Papert has suggested that LOGO clearly fulfilled his 'continuity' and 'power principle,' but he was uncertain if LOGO activities had 'cultural resonance.' The evidence from these eighteen case studies suggest that all Papert's principles can be met using computer-based information-handling packages.

There is little question of meeting the 'continuity principle' if this is defined by the content areas covered. In cases where it was not fulfilled teachers and children had general selected a topic because it would fit nicely on to the data-base rather than for any inherent value in the data itself. These examples were rare and comprised only 17% of the sample. On the whole the topics were developed with a greater purpose than satisfying the appetites of the computer.

If the 'continuity principle' is defined in terms of level of thought then children in these case studies were frequently asked to perform at higher levels than Piagetian theory would predict possible, and the 'continuity principle' was therefore not met. For example, the youngest children (5-7 years of age) were required to operate a constraint hypothesis strategy which is founded on the concept of equivalence. Piagetian restraints were violated in a number of studies as children learnt to cope with negative questions and showed abilities to decentre their thinking. In the studies CS9 and CS10, children wrestled with the problem of the logical 'and,' a highly abstract concept, although only one of the two groups (CS9) came to an understanding of this concept.

Some of the most stimulating classroom outcomes occur because profound issues arise naturally out of the use of computers, presenting children with the conceptual conflicts that all learning theories agree are necessary for cognitive growth. Sherry Turkle (1984), in a very different context, also provides evidence of how the confrontation with computers leads to such growth, as children are faced with the issues of life and death, and of the nature of humanity, when coping with a responsive and 'intelligent' machine.

The 'power principle' is clearly illustrated in a number of studies as children slowly mastered complex issues of data organisation and, not only retrieving, but making sense of information. Often the computer format forced children to resolve issues as in CS10 where the children began to develop an understanding of 'biting and stinging.' The influence of the computer on classificatory ability has also been noted in Experiment 5.

The use of data-bases fulfilled the principle of 'cultural resonance' in two ways. At its simplest, information processing skills in general, but particularly those associated with computer packages, are valued in our society. The use of data-bases encourages active learning, however, and those skills of leadership and group cohesion noted here are also perceived as adult and valuable. Only in educational institutions is there such a strong emphasis on working alone and not sharing ideas. This traditional approach to education was not apparent in these studies at all.

In conclusion, these eighteen case studies collectively provide considerable support for the argument that use of computer-based information-handling packages in schools will be beneficial. Powerful learning situations can occur and children can begin to develop valued skills and knowledge. Not all the case studies should be viewed with such euphoria, however. There were examples of missed learning opportunities in virtually all the studies and, one or two studies, appeared to record few transactions and outcomes of any value at all. Equally there were exciting educational events often stimulated by the teachers but also developing from the children themselves, and it is possible that it was this partnership which most excited the majority of teachers, many of whom were eager to repeat this experience with other classes.

CHAPTER 9

THE ROLE OF THE COMPUTER IN DEVELOPING CHILDREN'S CLASSIFICATORY ABILITIES: TUTOR AND DESIGN PROGRAMS IN THE CLASSROOM

9.1 Introduction

In Experiment 5 (Chapter 7) it was established that using the computer in the classroom could have beneficial effects on children's classificatory abilities. That experiment demonstrated that children who used computer based information handling packages, as part of their project work, showed differentially improved performances on a simple classificatory task, compared to students involved in the same project but not having access to the computer data-bases. It was suggested that this differential gain could be explained partly by the motivating effect of the computer, particularly in stimulating the individual child's self-esteem, but also by the very rigidity of interactions between the computer and child, which forced the children to think carefully about the organisation of their data and to be meticulous in the construction of questions to retrieve information from the data-base.

In the following two experiments the aim was to investigate whether or not classificatory ability could be stimulated by the use of other computer software which, although requiring children to complete classificatory tasks, presented very different approaches to the teaching/learning situation.

9.2 Experiment 6: The Use of Tutor Programs in Schools

9.2.1 Introduction

The aim of Experiment 6 was to investigate whether children's classificatory ability could be stimulated by a more traditional learning approach than that used in Experiment 5, through the use of a tutoring package with a strong emphasis on skills practice. The specific aims of the study were two-fold:

1. To Investigate the extent of the development of classificatory skills, as measured by a simple pre-post categorisation task, for children involved in a learning programme which involved both direct instruction and classificatory skills practice.

Hypothesis 1: Involvement in a relevant tutoring programme will lead to an improvement in children's classificatory abilities.

2. To investigate whether the teaching strategy employed, in this case teaching with or without the aid of a micorocomputer and relevant software, would significantly influence the acquisition of classificatory skills.

Hypothesis 2: Children working within different teaching strategies will show differential improvement in classificatory ability.

9.2.2 Method

Subjects

Twenty-nine children, aged 10 to 11 years, were assessed for reading ability, (McLeod, 1970), and for their non-verbal ability (Raven, 1956). The children were further assessed on their ability to complete a simple 'twenty questions' type categorisation task which is described in detail in the procedure for Experiment 5.

Table 9.1

Ability profiles of the Children in the Two Experimental Conditions

		Mean age	Mean reading score	Mean non-verbal score	Mean Pre-categorisation score
Computer group (N=12)	**LC**	10.9 (0.28)	24.7 (5.21)	16.6 (5.43)	7.9 (2.41)
Control group (non-computer) (N=12)	**LN**	10.9 (0.29)	24.4 (5.19)	16.0 (6.44)	7.7 (1.87)

S.D. in brackets

The three test scores were used to establish two experimental groups, each of which contained twelve children. The mean test scores for the children are presented in Table 9.1.

Materials

The pre-post categorisation test materials. Test materials for the pre-post categorisation task consisted of two matched sets of twenty-four cards with a simple line drawing in black ink on white card, as described in Experiment 5.

The computer program. The computer software **LOGIBLOCKS 2** (Shiva, 1984) is a suite of programs designed to encourage the development of classificatory abilities through tutorial guidance and practice in the the categorisation of two and three dimensional shapes, the latter being represented by two dimensional drawings. The programs are carefully graded and offer practice in a games format. The games are designed to be played individually but can be used by two or three children together. The programs draw on familiar primary school activities designed to encourage classificatory skills through the manipulation of concrete materials. **LOGIBLOCKS 1** consists of simple sorting games along one or two dimensions and may be used with children as young as five years of age, although the graded exercises are designed for children in the age-range of six to eight years. The programs used in Experiment 6, **LOGIBLOCKS 2**, require children to apply their classificatory skills in a series of problem solving games. Classification may occur on one, two or three dimensions and the more difficult games have a time element which can be pre-set by the child or the teacher.

The software documentation includes a booklet of support exercises to be used by the children when not working with the computer. These exercises are generally board game simulations of the computer games. In the present study they formed the basis of the work completed by the children in the control group, but were not available to the computer group.

Design

In this mixed factorial design experiment there was one between-subjects factor and one within-subjects factor. The two experimental groups each received the pre- and post-categorisation tests along with all members of the contributing class. All subjects completed a programme of work based on a suite of graded categorisation games. The children worked with the same adult who was not the experimenter on all occasions. The games were presented on the computer to the experimental group **LC**. The 'knowledge of results' aspects of the computer programs was provided by the adult working with the children in the control condition **LN**.

Procedure

Pre-post testing The procedure for administering the pre- and post- categorisation task was the identical to that of Experiment 5.

Developing classificatory abilities. All twenty-nine children in the sample class were involved in a three week work programme which involved the children in graded series of classificatory games. Care was taken not to distinguish the twenty-four members of the experimental groups from the remaining members of the class in order to reduce experimenter bias. The children worked in groups of three which were not fixed, rather they were formed by the availability of any three subjects within a condition. All work took place in the children's normal classroom as part of an integrated programme of work. All groups were led by the same adult who was not the experimenter.

Initially each triad was introduced to one of the simple games either on or off the computer, depending on the experimental condition they were assigned to. Over the following three weeks the children worked with each of the games and each child played every categorisation game at least twice. All the children proved proficient players of the simplest games and showed greater enthusiasm for the more demanding games. The children were, therefore, allowed to concentrate on those games and each child was involved in the demanding games on six to eight occasions.

The term 'more demanding' here refers to both the number of dimensions upon which the classificatory descision was to be based and to the nature of the game. The harder exercises asked children to complete relational equations such as :

Shape 1 is to ???? as Shape 3 is to Shape 4

or to place an object rapidly in a partially completed matrix, when the missing objects were presented in random sequence to the child. In this latter program the teacher or child could set a time limit to the task. In the control situation (**LN**) a large clock was used to provide the speed incentive for those children who wanted to test themselves in this way. This element of self-selection was important as it was an integral part of the comperable computer game.

In order to remove, or at least reduce, any perceptions of being treated differently, the children in the control group **LN** were involved in a programme of work using the computer for text processing.

9.2.3 Results

Scoring

Pre-post categorisation test. Subjects were assessed on the mean number of questions required to identify the target card on each trial, as in Experiment 5.

Analysis

Pre-post categorisation test. A split-plot analysis of variance was performed on the mean number of questions per trial provided by each subject in each condition. The two factors were teaching strategy (between-subjects factor) and pre-post classification scores (within-subjects factor). There was a significant improvement in performance for subjects as a whole on the pre- versus post-categorisation task ($F=6.29$; $df=1,22$; $p<0.02$). The mean number of questions required to identify the target word was lower on the post test ($X=7.24$) as compared to the pre-categorisation task ($X=7.80$), but there was no reliable difference in performance between teaching strategies (**LC**, $X=7.45$; **LN**, $X=7.59$). The interaction between teaching strategy employed and performance on the pre-/post-categorisation task failed to reach significance ($F=1.62$; $df=1,22$; n.s.).

Further analysis showed that the pre-categorisation scores for the computer and non-computer groups were virtually indistinguishable ($F<1$), nor was there a reliable difference between the pre- and post-test scores for the non-computer group **LN** ($F<1$). The computer users **LC**, however, did show improved performance on the post-categorisation test ($F=7.15$; $df=1,22$; $p<0.02$), as is shown in Table 9.2. Although there was no reliable difference in post-test performance between the two teaching groups **LC** and **LN** ($F=1.76$; $df=1,22$; n.s.).

Table 9.2

Mean Number of Questions per Trial for the Pre-Post Categorisation Test, across Teaching Strategy.

	Pre-test	Post-test
Computer group **LC**	7.88 (2.41)	7.03 (2.52)
Non-computer group **LN**	7.73 (1.87)	7.45 (2.52)

- S.D. in brackets

An analysis of the ratio of constraining to specific questions, as performed in Experiment 5, showed that the pattern of improved performance for the computer group was less robust than in Experiment 5 (Table 9.3). There was no difference between groups in the pre-test situation ($F<1$) nor in the post-test situation ($F=1.43$; $df=1,22$; n.s.), and there was no improvement in the performance of the non-computer user group **LN** over the period of the investigation ($F<1$). This was also true for the computer user group **LC** ($F=3.64$; $df=1,22$; n.s.) although a trend of improvement was discernable suggesting that this group was more likely to use a classificatory strategy in the post-test situation.

Table 9.3

Mean Number of Constraining Questions to Specific Questions per Subject for the Pre-Post Categorisation Test, across Teaching Strategy (N=21).

	Pre-test	Post-test
Computer group **LC**	0.59	0.80
Non-computer group **LN**	0.61	0.66

As in Experiment 5, the Pearson Product Moment Correlation was used to investigate the relationship between individual student performances in the pre-post categorisation task, with the general measures of reading and non-verbal ability. There was no relationship between ability levels and pre-test reading ability ($r=-0.20$; $df=20$; n.s.) and non-verbal ability ($r=+0.21$; $df=20$; n.s.) or post-test reading ($r=-0.10$; $df=20$; n.s.) or non-verbal ability ($r=+0.34$; $df=20$; n.s.) performances but post-test scores were highly correlated to pre-test scores ($r=0.90$; $df=22$; $p<0.001$).

The lack of a relationship between ability levels and the pre- and post-test performances is puzzling and is not consistent with the findings in Experiment 5. Scatter plots of the data confirmed the lack of relationship and made apparent that the lack of pattern in the data was not a result of a small number of outlying scores. Further, the strength of the relationship between the pre- and post-test scores suggests that the experimental manipulation can only partially explain improvements in categorisation performance.

When initially setting up the experimental groups one little girl had been excluded from the study because she scored very badly on the non-verbal test while performing at a very high reading ability level. The class teacher commented that this child suffered severe anxiety when faced with something new, as in the Raven's test. It is possible that some of the children in this class were more likely to be anxious in novel situations than other children used in this series of experiments and under-performed on the ability tests, particularly on the novel Ravens test. This would not invalidate the results of the experiment as matching was primarily on pre-categorisation scores and the relationship between these scores and the post-categorisation test scores in this experiment was consistent with those found in Experiments 5 and 7.

9.2.4 Discussion

The pre-post categorisation task and the tutorial programme required the children to employ comparable strategies to resolve the problems set in both situations and, because of this, it was anticipated that there would be an overall improvement in performance on the categorisation task by subjects in both experimental groups, although the computer users might be expected to outperform the control group. Such an improvement in performance did occur, but the results are not as clear or as easy to interpret as those of Experiment 5. The overall gains were small and further analysis showed that they were related to the use of the computer.

The computer users performed significantly better on the pre- versus post-test, unlike the non-computer users, but they did not significantly out-perform the non-computer users in the post test situation. The results imply a small advantage of teaching strategy, that is teaching with, as opposed to without, the computer. The large predicted performance gains due to the similarity of the learning task and the test task were not apparent, however.

As in Experiment 5, it is not possible to unequivocally identify the reason why the computer group should fare better than the non-computer users. Possible explanations fall into the two types: disparity of treatment of the two experimental conditions and the nature of the interaction between the user and the computer. In conducting the experiment great care was taken to match the operations off the computer to those presented on the machine. This was easy to achieve as the program documentation provided ready-made board games which simulated the computer games. Of course, in the control condition the adult had the important role of arbitrator and provider of 'knowledge of results' to the children, a role fulfilled by the computer for the experimental condition. It can be argued that the differences between the two conditions were minimised, if not removed , by this careful matching of procedure.

If we reject the disparity argument then the differences in recorded performances need to be explained in terms of child-computer interaction. The motivational aspect of the computer were always evident, the children needed no encouragement to join in the games. Indeed, the class teacher commented that some children were more motivated to complete non-related work in order to be ready when their turn to 'play' came about. His comments did not apply to the control group but the children did exhibit considerable enthusiasm when playing the board games.

There are other factors to be considered, however. Although care was taken to mimic the computer in all relevant operations, however careful the adult worker was in her attempt to be machine-like, she still formed a significant figure in the working group and it could be argued that an adult as arbiter of success in the non-computer group would be inhibiting to the children. As a consequence of this the children might have viewed the exercise as a traditional classroom experience, becoming more circumspect in the solutions they put forward, and watching carefully for signs of adult approval or disapproval.

Video tape evidence of pilot work, undertaken at the start of this research project with a group of less able ten and eleven year olds, showed that the children often respond rather differently to corrective information feedback from the computer than to information from adults. In one video sequence three little boys deliberately and repeatedly gave incorrect answers to a simple mathematical problem in order to receive, what appeared to the experimenter, a very harsh judgement of their performance by the computer. This reduced the children to fits of uncontrollable laughter and appeared to be a cathartic action against authority by children who were frequently tested and found wanting by the academic system.

A second video sequence showed a little boy becoming increasingly irate with the computer which corrected what he felt was a perfectly good answer to the set question. The child eventually abandoned the computer because it was 'unfair' and went to a different machine. Throughout the remaining ten week period of work this little boy refused to work at the offending machine. The important point here is that a child labeled inadequate, with a history of academic failure, was willing to question the authority of the computer and to put forward a cogent, if misguided argument, as to why his answer was correct and the machine's wrong. It is difficult to envisage the same child challenging his teacher in this way. Indeed, Hughes (1986) cites several instances when even highly able children accepted incorrect information from a teacher without raising a single objection. It would appear that, for some children at least, the computer has a similar status to Donaldson's (1978) 'naughty teddy;' a source of information which can happily be queried because it is less of an authority figure than an adult, and making mistakes in front of it is not damaging to the child's self-image. This reduction in the 'fear of failure' could prove to be a powerful motivator for all children, but particularly for the less able or the anxious child.

The children might have benefited from interacting with the computer, not just because it is motivating, but also because of the swift response of the computer to the child's actions, which could have lead to a greater bonding between the child's input and the correct answer. As in Experiment 5, the adult would have provided rapid responses in the simpler games but delays might have occurred in the more complex games. For the less able subjects, in particular, the immediacy of feedback when playing the computer games, may have proved important as answers could be provided before attention strayed and the memories of the question under review faded.

Wine (1971), in investigating the adverse effects which test anxiety has on task performance, has shown that there is an attentional interpretation of performance. The highly anxious person divides his attention between self-relevant and task-relevant variables, in contrast to the the low-test-anxious person who focuses his attention more fully on the task and, therefore, has greater processing capacity available for solving the problem to hand. A similar situation of divided attention can be argued here. The presence of the adult might have caused the children, particularly those more anxious members of the group, to divide their attention between the game and the adult, only partly concentrating on solving the classificatory problems of the game, with the consequent limited improvement in performance on the post-categorisation test.

In summary, the main finding of this study was that teaching strategy led to an improvement in classificatory skill. The strength of association between the pre- and post-test performance scores can not be ignored, however, in any explanation of the experimental results. It cannot be argued that the experimental treatment allowed these children to enhance or compensate for their initial reading or non-verbal abilities. The lack of relationship between these abilities and the pre-categorisation scores is not easy to explain. What is apparent from the study is that the children in the computer group made a small differential gain in performance over the control group, and that the explanation for this gain lies partly in the power of the computer to motivate children and in the nature of the interactions which occur between the computer and the child.

9.3 Experiment 7: The Use of Design Programs in Schools

9.3.1 Introduction

The aim of Experiment 7 was to investigate whether children's classificatory ability could be stimulated by encouraging children to think in new ways about everyday objects through the use of a design program based on Edward de Bono's (1978) concept of lateral thinking. The specific aims of the study were two-fold:

1. To investigate the extent of the development of classificatory skills, as measured by a simple pre-post categorisation task, for children involved in learning programme which involved both novel mental manipulations of concepts and application of these new insights to specific problems.

Hypothesis 1: Involvement in a relevant lateral thinking programme will lead to an improvement in children's classificatory abilities.

2. To investigate whether the teaching strategy employed, in this case teaching with or without the aid of a micorocomputer and relevant software, would significantly influence the acquisition of classificatory skills.

Hypothesis 2: Children working within different teaching strategies will show differential improvement in classificatory ability.

9.3.2 Method

Subjects

Twenty-nine children, aged 10 to 11 years, were assessed for reading ability (McLeod, 1970), and for their non-verbal ability (Raven, 1956). The children were further assessed on their ability to complete a simple 'twenty questions' type categorisation task which is described in detail in the procedure for Experiment 5 and 6.

The three test scores were used to establish two experimental groups, each of which contained twelve children. This was further reduced to a group size of eleven because of one child's absence during part of the learning programme.The mean test scores for the children are presented in Table 9.4.

Table 9.4

Ability profiles of the Children in the Two Experimental Conditions

		Mean age	Mean reading score	Mean non-verbal score	Mean Pre-categorisation score
Computer group (N=11)	TC	10.8 (0.31)	29.5 (4.97)	19.4 (4.52)	6.89 (0.91)
Control group (non-computer) (N=11)	TN	10.9 (0.29)	29.6 (4.80)	19.9 (3.81)	6.89 (1.02)

S.D. in brackets

Materials

The pre-post categorisation test materials. Test materials for the pre-post categorisation task consisted of two matched sets of twenty-four cards with a simple line drawing in black ink on white card, as described in Experiment 5 and 6.

The computer program. The programs which formed the basis of Experiments 5 and 6 simulated classificatory activities either by requiring children to organise information in order to resolve specific problems (**SEEK** and **FACTFILE**) or, by giving overt classificatory practice (**LOGIBLOCKS 2**). In this final experiment the program used was **THINKLINKS** (Straker, 1983), a program to stimulate children's skills in design through encouraging lateral thinking. De Bono regards design as a higher-level cognitive skill than problem-solving, because "Design is more open-ended than problem-solving. It requires more creativity." (1978, pp.247). For de Bono the open-endedness of design extends the child's thinking beyond the specific goal orientation of problem-solving.

Whether design is one element of, or an extension beyond, problem-solving, it is generally perceived as a worthwhile educational activity. In **THINKLINKS** children's ability to design is developed through a series of increasingly complex activities. Initially children are asked to classify, on a range of criteria, five randomly selected objects presented by the computer. For example, they may be requested to grade the following objects on the criterion of softness: matches, a shoe, water, a spade and a table. This encourages children to view objects in new ways. The second phase of the game is to use five randomly presented objects to solve a computer selected problem such as crossing a stream, catching a fish, or, getting into a house for which you have lost the key. Finally the children are asked to invent or design a device to solve a problem such as sorting potatoes or catching a mouse (see Underwood, 1986).

At first sight this type of lateral thinking exercise appears to be an activity which can gain little from being computerised, as all that is necessary is a mechanism for providing the random list of words and design problems. Output to the screen is confined to text and the children's only input to the program occurs when they request another list of words or problems. The computer program proved very easy to replicate as a card game with appropriately marked cards and the adult experimenter randomly dealing out the pack .

Design

In this mixed factorial design experiment there was one between-subjects factor and one within-subjects factor. The two experimental groups each received the pre- and post-categorisation tests along with all members of the contributing class. All subjects completed a programme of work based on de Bono's (1978) design game to encourage lateral thinking. The children worked with the same adult who was not the experimenter on all occasions. The games were presented on the computer to the experimental group **TC**. The problem generation aspect of the computer program was provided by the adult working with the children in the control condition **TN**.

Procedure

Pre-post testing The procedure for administering the pre- and post- categrisation task was the identical to that of Experiment 5 and 6.

Developing classificatory abilities All twenty-nine children in the sample class were involved in a three week graded programme of work which encouraged them to think in new ways about ordinary, everday objects; and to apply those new insights to the solution of specified problems. Care was taken not to distinguish the twenty-two members of the experimental groups from the remaining members of the class in order to reduce experimenter bias. The children were randomly assigned to groups of three within a condition. All work took place in the children's normal classroom as part of an integrated programme of work. All groups were led by the same adult who was not the experimenter.

In order to remove, or at least reduce, any perceptions of being treated differently, the children in the control group **TN** were involved in a programme of work using the computer for text processing.

9.3.3 Results

Scoring

Pre-post categorisation test. Subjects were assessed on the mean number of questions required to identify the target card on each trial, as in Experiments 5 and 6

Analysis

Pre-post categorisation test. A split-plot analysis of variance was performed on the mean number of questions per trial provided by each subject in each condition. The two factors were teaching strategy (between-subjects factor) and pre-post classification scores (within-subjects factor). There was a significant improvement in performance for subjects as a whole on the pre- versus post-categorisation test ($F=19.45$; $df=1,20$; $p<0.001$). The mean number of questions required to identify the target card was lower for the post ($X=6.18$) as opposed to the pre-categorisation ($X=6.89$) test. There was no reliable difference between teaching strategies (computer, $X=6.39$; non-computer, $X=6.67$), nor was there an interaction between teaching strategy employed and performance on the pre- versus post-categorisation task ($F=3.13$; $df=1, 20$; n.s).

Table 9.5

Mean Number of Questions per Trial for the Pre-Post Categorisation Test, across Teaching Strategy.

	Pre-test	Post-test
Computer group **TC**	6.89 (0.91)	5.89 (0.78)
Non-computer group **TN**	6.89 (1.02)	6.43 (1.38)

S.D. in brackets

Further analysis showed that the pre-categorisation scores for the computer and non-computer groups were indistinguishable ($F<1$), and there was no difference between pre- and post-test scores for the non-computer users **TN** ($F=3.48$; $df=1,20$; n.s.). The computer users **TC**, however, did not follow this pattern of results, as is shown by reference to the means of questions per trial (Table 9.5). There was a reliable difference in pre- and post-test scores for the computer users ($F=19.10$; $df=1,20$; $p<0.001$) and between post-test scores of the computer **TC** versus non-computer **TN** users ($F=6.26$; $df=1,20$; $p<0.05$).

This pattern of improved performance for the computer users was not apparent in the analysis of constraining questions. There was no difference between groups in the pre-test situation ($F<1$) nor in the post-test situation ($F=3.13$; df=1,20; n.s.). There was no improvement in the performance of the non-computer user group **LN** over the period of the investigation ($F<1$). This was also true for the computer user group **LC** ($F=3.94$; df=1,20; n.s.) although a trend of improvement was discernable suggesting that this group was more likely to use a classificatory strategy in the post-test situation.

Table 9.6

Mean Number of Constraining Questions to Specific Questions per Subject for the Pre-Post Categorisation Test, across Teaching Strategy (N=24).

	Pre-test	Post-test
Computer group **TC**	0.91	1.15
Non-computer group **TN**	0.87	0.98

As in Experiments 5 and 6, the Pearson Product Moment Correlation was used to investigate the relationship between individual student performances in the pre-post categorisation task, with the general measures of reading and non-verbal ability. There was a positive relationship between pre- test performance and both reading ($r=-0.45$; df=19; $p<0.05$) and non-verbal ($r=-0.50$; df=19; $p<0.05$) abilities, but these relationships were not apparent for the post test situation. Both reading ($r=-0.10$; df=19; n.s.) and non-verbal ($r=-0.35$; df=19; n.s.) abilities appeared to have little influence on the post-test performances. The post-test scores were correlated to pre-test scores ($r=0.65$; df=19; $p<0.01$), however.

The relationships between measured ability levels and the pre- and post-test performances is consistent with the results in Experiment 5. This suggests that the improved performances on the post-categorisation task were a result of the experimental treatment which, in the case of the computer users, had allowed the children to either enhance or compensate for the initial personal abilities they brought with them to the teaching programme.

9.3.4 Discussion

The evidence from this study again confirms that specific skills acquisition is possible with judicious teaching/learning strategies. There were overall gains in performance between pre- and post-categorisation tasks but the strength of those gains was governed by the teaching strategy employed. The computer users performed significantly better on the pre- versus post-test, unlike the non-computer users, and they significantly out-performed the non-computer users in the post test situation. The results imply an advantage of teaching strategy, that is teaching with, as opposed to without, the computer, although the strategy employed by the computer users in the categorisation task was not significantly different from that of the control group.

The question again arises as to why this disparity in skills acquisition should occur. The arguments for and against explanations involving disparity of treatment between groups and the nature of the interaction between child and machine have been presented in Experiments 5 and 6. In this experiment equal care was taken to match operations on and off the machine and, as the operations on the machine were very simple, involving the presentation of randomised lists, this matching process was extremely easy to achieve.

As a result of the simplicity of the computer operations, and the degree to which the children worked off the machine in the computer group, it is difficult, at first sight,to offer any explanation of the advantage of computer use in this experiment. Comments from the children in the non-computer group were illuminating, however. When presented with the task of organising five randomly selected objects along a novel dimension, as described in the procedural description of this experiment, several of the children appeared resistant to the task. Comments on the silliness of discussing the softness of a table were articulated and the adult working with the children was asked on several occasions to re-deal the cards (that is randomly select a new group of objects) to produce a more sensible problem. Although the adult resisted these overtures and continued to operate in a similar manner to the computer, there was no doubt that the interactions between the children and the adult were different to those taking place between the children and the computer. In the latter case, although the children were often puzzled by the unusual task set, they accepted it for a variety of reasons. One little boy said that the computer was made to act like that by people and it could not change. This was accepted by his group. Other children simply stated that the computer was funny but they carried on the task nevertheless.

The motivational argument appears less acceptable for this class of children for two reasons. The children were not computer naive. They had a computer permanently in their classroom and were using it for a wide variety of activites including adventure gaming. Neither can the software be described as exciting as it used few of the facilities of the computer in this electronic-book-mode. Equally, the argument pertaining to the rapidity of knowledge of results is irrelevant here as there was no interaction between the child and the computer other than when the user asked for another problem to be set.

The conclusion to be drawn here is that although a variety of hypotheses can be put forward to explain the results in this experiment, the insights into acceptable interactions between child and adult and child and computer, particularly the awareness that adults can be manipulated but 'machines are machines' and you have to accept that, do present a convincing argument as to the differential effectiveness of the two experimental conditions. In

Experiment 5 it was argued that the rigidity of acceptable interaction between the child and the data-base was a powerful influence on classificatory ability. The argument posed here is similar. Although there was no direct effect of the computer on the organisational structures produced by the children, the children's acceptance of both the rigidity and the difference of the machine to humans allowed the computer group to become more involved in the task at hand. In the non-computer group the task was seen by several children as silly and not worthwhile and these expressed attitudes provide a powerful explanation for the children's failure to gain from the learning situation.

In summary, the main finding of this study was that teaching strategy lead to an improvement in classificatory skill, and the computer users made differential gains over the non-computer users. The relationship between reading and non-verbal abilities and pre-categorisation performances was no longer evident on the post-test situation, suggesting that the experimental treatment had allowed the computer users to compensate for their initial abilities. It is suggested that the cause of this differential improvement lay in the nature of the interactions between the children and the authority figure in each of the conditions. Whereas the children, for a variety of reasons, were prepared to accept novel problems set by the computer, they were less accepting and more manipulative in their interactions with the adult authority figure.

Prior to the experiment, the main argument for using this software package might have been that it saved teachers time in producing workshheets and generating ideas, a view put forward by several teachers on seeing the program THINKLINKS. A more cogent argument following this trial, would be that the use of the computer can generate new relationships in the classroom which can encourage children to be more receptive to new ideas or ways of doing things.

9.4 A Comparison of the Findings from the Three Classificatory Investigations: Experiments 5, 6 and 7.

The purpose of this group of experiments was essentially two-fold: to establish whether or not children's classificatory abilities could be stimulated by a set programme of work, and, whether or not the use of the computer would lead to differential gains in performance over non-computer users. Direct comparisons between types of instruction, based upon data handling packages, direct skills practice and the concept of lateral thinking and design, were not built into this programme of research. Inevitably questions of the comparative effectiveness of these methods of presenting classificatory problems to the children arise from the results presented here. Some tentative comments will be made but, although the procedures and test items were identical for each experiment, the experimental groups were not matched across the three experiments. The group mean age and test scores are presented in Table 9.7 .

A comparison of the results from the three experiments showed that there was an overall improvement in performance on the post-, as compared to the pre-, categorisation task and that these improvements were a result of teaching strategy. In all three experiments the computer users made differential performance gains over the non-computer users.

Although the results suggested that improvements occurred for each instructional programme, the results appear most robust in Experiment 5, in which the children were asked to complete a data organisation and retrieval task. The computer users in this experiment not only improved their own categorisation performance and performed significantly better than the non-computer users on the post-test, they also were likely to use the more efficient hypothesis constraining strategy to resolve the 'twenty questions' problem, rather than an hypothesis scanning strategy.

Table 9.7

Ability Profiles of the Children in the Three Experiments

	Mean age	Mean reading score	Mean non-verbal score	Mean Pre-categorisation score
Experiment 5	10.5	19.5	17.2	8.3
Experiment 6	10.9	24.5	16.3	7.8
Experiment 7	10.8	29.5	19.7	6.9

In Experiment 7 similar differential gains were made by the computer users as compared to the non-computer users but, although the computer users show a trend to use the more efficient constraint strategy in the post-test situation this improvement is below statistical significance. In Experiment 6, the computer users do show significant gains in the post-test situation but they do not reliably outperform the non-computer users, although they do show a trend to greater use of the constraint strategy when completing the post-categorisation task.

Ability Levels

Correlational information on task performance and ability level is presented in Table 9.7. As was argued in Chapter 5, for successful completion of the categorisation tasks, children can legitimately be expected to draw on non-verbal abilities (Bruner, Goodnow and Austin, 1956) which should be related to measured reading abilities(Turner, Scullion and Whyte, 1984).

In Experiments 5 and 7 success on the pre-categorisation task was correlated with ability levels, results consistent with the findings of Experiments 1, 3 and 4. This was not true for Experiment 6 in which no discernable pattern was found between categorisation performance and the general measures of ability recorded in this experiment. The argument for a ceiling effect, posed to explain a similar anomaly in Experiment 2, was not valid here and the possibility of high test anxiety within this particular class of children seems to be one explanation, as has already been discussed.

Table 9.8

Correlations Between Reading and Non-Verbal Ability and Pre- and Post-Categorisation Task Performance for the Three Experiments.

Ability Level	Experiment	Pre-Test	Post-Test
Reading Ability	5	-0.426**	-0.179
	6	-0.197	-0.094
	7	-0.449*	-0.043
Non-verbal Ability	5	-0.451**	-0.336*
	6	+0.208	+0.329
	7	-0.499*	-0.275

n.b. A negative r score indicates a positive relationship.
Level of significance of the correlation: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

In the post-test situation, the relationship between ability levels and categoristion scores weakens. In both Experiments 5 and 7, there was no longer a relationship between reading and categorisation scores. The relationship between non-verbal ability and post-test performance weakened but was still present in Experiment 5 but disappeared in Experiment 7. Interestingly, although there was again no relationship between abilities and categorisation performance in Experiment 6, the direction of change in the correlations was the same in this experiment as in Experiments 5 and 7, that is the overall trend was to a reduced reliance on initial abilities in completing the post-categorisation task, clearly indicating an effect of the educational programme on the children's performance.

9.5 General Discussion

The three experiments were designed to investigate the ease with which young children's classificatory skills could be stimulated in the classroom through a variety of work programmes, with particular emphasis on the effectiveness of the computer in enhancing skills acquisition. In all three experiments the computer users out-performed the non-computer users. The non-computer programmes of work had disappointingly little effect on children's performances. The three investigations together show a gradation in performance gains, by the computer users, with the children using the information-handling packages being most successful, followed by those children involved in the exploration of concepts through a design programme with least gains being made by the group who received a tutorial programme of work.

The apparent low effectiveness of the guided tutorial programme of work was surprising for it offered activities closely related to the categorisation task. In their work with very young children (4 to 5 years of age), Lawton, Hooper, Saunders and Roth (1984) found that what they described as traditional instructional programmes, had little effect on children's classificatory skills. They compared the effects of three types of instruction defined as Ausebelian, Piagetian and traditional, on pre-school children's acquisition of logical concepts.

For Lawton et al., an Ausebelian programme emphasised the organisational structure of the knowledge to be learnt, as in the information-handling packages used in Experiment 5 which required children to think in terms of rules of organisation. To a lesser extent the **THINKLINKS** program, used in Experiment 7, operated a Piagetian mode of instruction, according to Lawton's definition. This was a self-discovery approach to learning, in which the child made spontaneous physical and mental manipulations of objects and the teacher acted as a facilitator guiding the child, through the judiceous use of questions, statements and suggestions aimed at arousing curiosity and motivation.

Lawton et al. defined a traditional mode of instruction as one which used many of the activities and materials of the Ausebelian and Piagetian approaches but without an underpinning theoretical approach. In Experiment 6, **LOGIBLOCKS 2** was considered to operate a traditional mode of instruction, but here 'traditional' was defined as learning through skills practice, a didactic rather than discovery learning approach.

Lawton et al. found that their young children in the Ausebelian programme, that is children who were encouraged to emphasis knowledge structures, were far more successful on a range of post- versus pre-categorisation tasks, than were children being taught in a Piagetian or traditional classroom. The results for the computer users in Experiments 5, 6 and 7 are consistent with their findings. Those children using information handling programs not only made post-test gains, they were also more likely to use the highly effective hypothesis constraining strategy to resolve the classsification problems, but this was not true for the THINKLINKS and LOGIBLOCKS 2 programs.

Problems do arise from the comparison of the results in Experiments 5, 6 and 7 to those of Lawton et al. Although the pattern appears to be similar, the instructional mode emphasising the structure of knowledge being most successful, followed by the self-discovery method and with little success coming from the traditional instructional programme, this is only true when comparing the computer user groups. Progress by the non-computer users was small, if it occurred at all. Yet Lawton et al. did not use computers!

Lawton and Wanska (1979), working with eight to ten year olds, have shown that knowing the structure of concepts merely in terms of the property of that concept is not sufficient for young children to successfully produce a hierarchical structure for those concepts, or to compare super and subordinate concepts within the hierarchy. They found that children need more than the knowledge that 'a mammal is a hairy animal which suckles its young,' in order to place that concept in the animal hierarchy. The children must be able to generate the rules governing that hierarchy, for example that the superordinate concept (animal) is defined by a property shared by all the subordinate concepts.

Lawton et al. (1984), in their Ausebelian programme, placed a heavy emphasis on this rule generation, and the children made commensurate classificatory progress. In Experiment 5, many of the activities described by Lawton et al. were undertaken by both the computer and non-computer users during the programme of work on cheeses. It was in questionning the data-base, however, that a clear understanding of the structure of the information, and the rules governing it, were most needed, and it was in this area that the disparity between computer and non-computer treatment may have occurred. It has already been stressed that to get an answer from the computer required great precision in questionning. This was further emphasised in the case study work (Chapter 7) which clearly showed the difficulties children of all ages had in gaining information from computer data-bases and the quality of thought required to resolve those retrieval problems.

When the adult in Experiment 5 was asked a question, in the simulated computer role, every effort was taken to be computer-like. It has already suggested that there might have been some loss in immediacy of feedback on more complex questions. It might also have been the case that, due to the shared knowledge of both child and adult, the adult was able to interpret and respond to less precise questions from the non-computer users. This unintentional lack of rigidity in the adult's behaviour would have allowed children to gain information without the precision of thought needed by the computer users.

That child-computer interaction can be different from child-adult interaction was clearly shown in Experiment 7. Here, the children were willing to accept a task defined by the computer, but the same task presented by an adult was rejected as nonsensical. The children in the non-computer group then tried to manipulate the adult and change the learning situation. This is a frequent and normal occurrence in the classroom, as John Holt (1970; 1969) has demonstrated in his classic books 'How Children Learn' and 'How Children Fail.'

The children reduced their role in finding the solution to the problem to hand, and encouraged the adult to take on part of the task, or to alter the task and make it simpler. In doing so the children may have reduced those conceptual conflicts that are generally believed to be vital to their own cognitive development.

In summary, the main findings of these three experiments were that the computer can be a powerful tool for encouraging children's classificatory abilities. The arguments presented here, to account for the results in Experiments 5, 6 and 7, are two-fold. Firstly children respond differently to the computer than to an adult. They appear to be aware that the computer is inflexible and that they must be the ones to adapt if communication is to take place. Some children go as far as treating the computer as a less able peer who must be helped. This inflexibility forces the children to greater precision in their own thinking. Secondly, children are more likely to accept novel ideas when presented by the computer, for the computer is different from a human being, it has a different status in terms of authority.

SECTION FOUR: CONCLUDING REMARKS

CHAPTER 10: SUMMARY AND CONCLUSIONS ON THE USE OF EDUCATIONAL COMPUTING

CHAPTER 10

SUMMARY AND CONCLUSIONS ON THE USE OF EDUCATIONAL COMPUTING

The research issues discussed here have all concerned the introduction of microcomputers into the school classroom. Although Chapter 1 outlined a number of pressing issues related to this educational innovation, the two main themes of this thesis are the receptiveness of the educational environment to the new technology, and the impact of that innovation on the recipient children themselves. In essence the questions relating to the educational environment are firstly how computers are being greeted by teachers and trainee teachers; and the state of cognitive readiness of children who are presented with selected software packages. The second theme concerns the impact of educational computing upon the development of children's minds. The choice of research themes does not negate the importance of other issues such as the influence of resource levels on effective implementation, nor does it reduce the importance of the computer in children's social development.

10.1 Attitudes towards the Innovation

The investigation of attitudes to classroom computers held by serving teachers and teachers-in-training has been set in the context of Kuhn's assertions on the nature of paradigm shifts. Such shifts are dependent on the rise of a new generation of workers uncommitted to established ideas and practice who are, therefore, capable of being receptive to innovative approaches. Kuhn does not say that a new generation will be receptive, only that they have the potential of being receptive to an innovation. The hypothesis tested here was that younger teachers would be more accepting of educational computing, but the hypothesis was disconfirmed in a surprising way: it was the older teachers who proved to be more enthusiastic than their younger counterparts.

In the study of attitudes to the computer, reported in Chapter 4, there were two main research goals: to measure and compare the attitudes of serving teachers and teachers in training, and to identify the factors influencing the development of those attitudes. The initial expectation, based on previous research (e.g. Lichtman, 1979; Johnson et al., 1981; Moore, 1985), was that attitudes to the computer would be largely negative. This pessimism proved to be largely ill-founded. In general, attitudes to the computer were positive, but there were varying degrees of acceptance. Four main attitudinal groups were identified by the cluster analysis. There was a continuum of acceptance from highly positive (27.5% of sample), through conditionally positive (27%) to those with generally negative attitudes (17.3%). Members of the fourth group (28.1%) were muted in their opinions, although more positive statements were made than negative. The sample as a whole expressed positive attitudes towards the computer four times more frequently than negative attitudes. These were not demand-effects for there was a careful balancing of direction of response for each item in the questionnaire. In the light of the strong gender bias found in previous attitudinal studies, the positive responses in this predominantly female sample are both surprising and encouraging.

Positive attitudes revolved around the potential of the computer to promote more child-centred learning and its usefulness across a wide spectrum of the curriculum. Where changes in the teacher's role were anticipated, they were viewed as beneficial, and linked to greater student autonomy. A division occurred between those who accepted the computer as a tool for most curriculum areas and those who feel it was still largely a scientific tool. Those expressing negative attitudes saw the computer as a restricted 'teaching-machine', providing low level educational inputs and no threat to the flexible role of the teacher. Coupled with this is a general feeling that the computer devalues, in some mechanistic way, the learning experience.

The study suggested that, while knowledge of the computer is seen as both relevant and worthwhile, and the predominant feelings towards computer use in schools are largely positive, there is an element of "let's wait and see." Surprisingly, serving teachers and post-graduate teacher trainees were disproportionately represented in the positive attitudinal groups. There was an expectation of a more enthusiastic response from the youngest 'teachers' who had been brought up in the 'computer age' and, indeed, could be expected to have met the computer during their own school-life. This did not prove to be so, however. Initial degree teacher trainees were disproportionately represented in the small group expressing hostile attitudes to classroom computers. Further analysis of the factors influencing the expressed attitudes showed that those expressing the most positive attitudes are more likely to work in the Sciences rather than the Arts, but not all scientists were positive and certainly many artists expressed interest in, and enthusiasm for, the new technology.

The rejection of classroom computers by the newest generation of teachers (the B.Ed. students) would be a cause for considerable concern if Kuhn's arguments held good, but the positive response from the serving teachers and post-graduate students indicates that attitudes to 'new things' are not as entrenched as Kuhn's argument suggests. Another encouraging point is that the members of the sample, who rejected the computer in the classroom, based their opinions on limited knowledge. If these young teachers had used the computer in their own school-life it must have been for a very restricted purpose which left them with little understanding of the power of the machine for educational purposes. As their level of computer literacy rises there is every hope that more favourable attitudes may ensue. Such a view is substantiated by the finding that those who are most positive towards classroom use of the computer are also those who are the most knowledgeable members of the sample.

This study of attitudes suggested that there is a great deal of informed interest and good-will towards the use of computers in the classroom. Indeed the expectations of the most positive teachers were very high indeed. As Clark (1984) has commented, generations of teachers have pinned their hopes on innovatory practices, especially those with a high technological input, to resolve the problems of the classroom. The question here is whether the new technologies can live up to these high expectations. The remaining research reported here considered this question in relation to the development of children's classificatory abilities.

10.2 Educational Computing and Children's Minds

The investigations reported in Chapters 6 to 9, concerning the role of the computer in the development of children's classificatory abilities, had two main strands. The pivotal investigation was the effectiveness of data-base use in the classroom. This work was stimulated by the rapidly increasing use of computer-based information handling packages in schools. In Chapter 6 an important environmental factor, that of the children's level of knowledge prior to treatment - in this case, the types of organisational structures available to them - was assessed prior to an empirical investigation of the benefits of data-base use on children's classificatory ability which was reported in Chapter 7. While in Chapter 8, an analysis eighteen of case studies of classroom data-base use questionned whether teachers are encouraging children to make the most of their experience of working with a computer data-base. Chapter 9 presented a comparison of classificatory development using three teaching strategies.

The evidence from the investigations on types of organisational structure available to young children (9 - 11 years of age) encourages us to approach the use of information handling packages with caution. The children, when asked to organise a group of words to indicate semantic relationships, tended to form lists of words using only one classificatory criterion. They had little success with two-dimensional organisations such as hierarchies, tables and networks. The dominance of the list structure for the majority of children, and the poor performance on all other structures masked individual differences and the influence of ability measures. On a more hopeful note for those working with young children, Experiment 4 showed that the children were able to extract data from hierarchies, networks and tables, although scores hovered around the fifty percent success point. We might, therefore, expect junior school children to use, if not construct, each of these organisational structures with similar facility. Non-verbal ability proved to be a key predictor of the ability to extract data from a given structure, although reading ability was also highly correlated with the successful use of networks and tables.

In Experiment 5 (Chapter 7) children were again asked to build organisational structures and to retrieve information from those structures, but the work was now in the context of an extended work project on the topic of cheeses. In this experiment the objective was to investigate the impact on children's classificatory ability of a project which emphasised information-handling skills. Would children (9-11 years of age) show a measurable improvement on a pre-post categorisation test through participation in a task involving the classification of familiar objects. In addition, any gains made were to be considered in the light of the type of organisational structure (hierarchy or table) used and the teaching strategy (with and without a computer) employed. Finally would the teaching strategy employed (working with or without a computer) influence children's acquisition of a specific body of knowledge.

Children using the two types of organisational structures, a binary-tree hierarchy and a matrix table, produced indistinguishable results on the pre- and post- categorisation task. This is consistent with the findings in Experiments 1 to 4, and is at variance with the results of work with adult subjects by Durding et al. There was also no difference in performance on the test of factual learning for children in these two groups defined by organisational structure. The main influence on the level of factual recall by the children was reading ability. There was no significant influence of teaching strategy.

The evidence from this study did confirm, however, that it was possible to aid skills acquisition with judicious teaching/learning strategies. There were overall gains between the pre- and the post-categorisation tasks but the strength of those gains was governed by the teaching strategy employed, computer users out-performing non-computer users. Although a number of explanations of this result were considered, there were three factors which provided the most persuasive arguments for the differential improvement of computer users over non-computer users. Firstly the use of computer data-bases demanded a rigour, particularly in information retrieval, which was not the case in the child-adult interaction. Secondly despite the level of control operated by the computer, it was suggested that the children felt a greater sense of responsibility for, and therefore power over, their own actions when working with the machine rather than interacting with an adult (cf Papert, 1981). Such a sense of control might have lead to greater self-esteem (Papert, 1981; Golden; 1982), and be motivating in itself. Alongside this 'power hypothesis' it could be argued that the swift response of the computer, particularly on more complex questions, might have lead to a greater bonding of question and answer. This immediacy of feedback may have been particularly important for the less able students.

The main findings of Experiment 5 were that a teaching strategy involving the use of a computer data-base, whether hierarchical or tabular in organisation, lead to a differential improvement in classificatory ability compared to that of non-computer users. The factual recall of information following the experimental treatment was related to reading ability, however, rather than to the main experimental conditions of teaching strategy or organisational structure. The computer had not proved to be an effective tool for the transmission of factual knowledge but it did stimulate the development of high level cognitive skills required for knowledge organisation.

The analysis of eighteen case studies reported in Chapter 8 was designed to shed light on both the aspirations and realities of teachers using computer data-bases in the classroom. All participants were positively disposed to the use of computers in the classroom. The teachers expressed a number of aims for their use of data bases, and these intents showed a collective knowledge of current educational thinking in the area. The recorded transactions and outcomes from the use of computer-based information-handling packages did not match intentions, however. The cause of this disparity appears to be the shift in focus of attention from global issues during the planning phase (specification of intentions) to the pragmatics of learning and classroom management, and the responses of individual children, during the action stage.

These eighteen case studies collectively provided considerable support for the argument that the use of computer-based information-handling packages in schools can be beneficial. Powerful learning situations occurred and children began to develop valued skills and knowledge. In particular the use of the computer data-bases forced children to grapple with concepts which either rarely occur in classrooms, for example the Boolean 'And', or which occur at an earlier stage in the children's cognitive curriculum than would normally be anticipated, for example the use of constraint hypotheses by children in the lower primary school.

Not all the case studies should be viewed with such euphoria, however. There were examples of missed learning opportunities in virtually all the studies and, one or two studies, appeared to record few transactions and outcomes of any value at all. Equally there were exciting educational events often stimulated by the teachers but also developing from the children themselves. It is possible that it was this partnership which most excited the majority of teachers, many of whom were eager to repeat this experience with other classes.

In Experiment 5 (Chapter 7) it was established that using the computer in the classroom had beneficial effects on childrens' classificatory abilities. In Experiments 6 and 7, the aim was to investigate whether or not classificatory ability could be enhanced by the use of other computer software which, although requiring children to complete classificatory tasks, presented very different approaches to the teaching/learning situation. The aim of Experiment 6 was to investigate whether children's classificatory ability could be stimulated through the use of a tutoring package with a strong emphasis on skills practice. The aim of Experiment 7 was to investigate whether children's classificatory ability could be developed by encouraging children to think in new ways about everyday objects through the use of a design program based on Edward de Bono's (1978) concept of lateral thinking.

A comparison of the results from the three experiments showed that there was an overall improvement in performance on the post-, as compared to the pre-, categorisation task and that these improvements were a result of teaching strategy. In all three experiments the computer users made differential performance gains over the non-computer users. Although the results suggested that improvements occurred for each instructional programme, the results appear most robust in Experiment 5, in which the children were asked to complete a data organisation and retrieval task. The computer users in this experiment not only improved their own categorisation performance and performed significantly better than the non-computer users on the post-test, they also were likely to use the more efficient hypothesis-constraining strategy to resolve the 'twenty questions' problem, rather than an hypothesis-scanning strategy.

The non-computer programmes of work had disappointingly little effect on children's performances. The three investigations together show a gradation in performance gains, by the computer users, with the children using the information-handling packages being the most successful, followed by those children involved in the exploration of concepts through a design programme with the least gains being made by the group who received a tutorial programme of work. This pattern of results of the effectiveness of the different teaching strategies is similar to that found by Lawton et al. (1984) working with pre-school children in a non-computer environment.

The main findings of these three experiments were that the computer can be a powerful tool for encouraging children's classificatory abilities. The arguments presented here, to account for the results in Experiments 5, 6 and 7, are two-fold. Firstly children respond differently to the computer than to an adult. They appear to be aware that the computer is inflexible and that they must be the ones to adapt if communication is to take place. Some children go as far as treating the computer as a less able peer who must be helped. This inflexibility of the computer forces the children to greater precision in their own thinking. Secondly, children are more likely to accept novel ideas when presented by the computer, for the computer is different from a human being: it has a different state of authority.

10.3 Future Research

While future research must necessarily answer the criticisms of these current studies it must also take our knowledge of classroom computer-use forward. The explanatory arguments offerred above imply that there were specific attributes of the medium, that is the computer and accompanying software, which influenced the acquisition of information-processing skills. As has already been noted Clark (1983, 1984) would disagree with this conclusion. He offers two powerful criticisms of classroom-based empiricism: the failure of the researchers to account for either the teacher variable, or the fall-off in performance gains over very short time-spans, that is the novelty effect. He is particularly scathing about short experimental treatments. Clark argues that the teacher variable can account for virtually all the variance in performance reported in media studies from the American literature. This is not the case for the studies presented here, however. The same teacher was responsible for the work of all the children within any one experiment, regardless of the experimental condition. This is not to say that all teachers, or all children, will achieve the results reported here. The studies only show that there are potential gains to be made.

Clark's 'novelty' criticism is less easily dismissed, however. Are the findings presented here robust and would performance gains still have been evident if the study had taken eight, and not four weeks, to complete? In the case of Experiment 5, the brevity of the treatment was governed by the time the children took to complete the classificatory task and was not pre-set by the experimenter. Replications of this study might consider lengthening this time-scale. This would be easy to do if the children had been involved with a larger data-base or had had to go out into the environment to collect their data input. Such excursions might involve collating library material, taking field-measurements or designing and operating a questionnaire. Examples of all of these approaches are found in the case study material reported in Chapter 8. The experimenter's provision of the cheeses in Experimenter 5 reduced the time required by the children to complete the process of designing and exploring their data-base. The time-scales used in Experiments 6 and 7 were designed to match that of Experiment 5.

In addition to extending the time-scale of such studies it would prove beneficial to monitor the robustness of the findings over time by taking repeat performance measures at a subsequent date. This was not possible in the current studies as many of the children changed schools a short time after the trials had been completed. In general there are cogent arguments for long term studies when considering the effectiveness of any educational treatment. As Snow and Yalow (1983) have shown, gains due to specific educational treatments can have long term effects. Such treatments which influence the child over time are the educationalists' Holy Grail, and they need to be clearly identified. This is only possible in large-scale collaborative research. In this sense the current studies are pilot experiments indicating a potentially fruitful area of research.

A second extension of the work reported here concerns the studies of those organisational structures available to children. Although it is important to establish the level of prior knowledge of users as one indicator of performance and as a base line to development, it is also important to establish the changing nature of organisational structures which occur as contact with specific data-bases takes place. Future work may, therefore, include investigations of the children's cognitive maps of data-bases.

A further question should consider whether the benefits shown when children construct computer data-bases, can be extended to other areas of the curriculum, such as language and music, where the computer can also be used as a tool. Do children show improvements in high level cognitive skills through the use of the word processor or a story tree as suggested by Daiute (1985) and Rubin (1983), or through the use of music programs such as COMPOSE (ITMA, 1986)?

Finally, although the results of the attitude questionnaire are encouraging it would be useful to know whether or not the good intentions and high hopes expressed by the majority of the participants have been translated into classroom realities. A follow-up study of participants representative of the four attitudinal groups would prove enlightening. Are those trainee-teachers who had positive attitudes to the computer actually using it in their own classrooms? If they are, what types of activities are they most involved in? If they are not using the computer, is this because of force of circumstances or have they subsequently become disillusioned? This study has yet to be undertaken as it was felt necessary to allow a minimum three year time-lag between the initial investigation and this later selective interviewing of candidates. The trainee-teachers need to be established in their classrooms, away from the pressures of a post-training probationary year, before this additional burden is placed upon them.

10.4 Promises and Products

Collectively the findings reported here lend considerable support to the advocates of classroom computer use. There appears to be a fund of good will towards the new educational technology. That good will is generally founded on prior knowledge of, and experience with, the computer. The most negative responses were from the least informed teachers. A result in line with that of Opacic and Roberts (1985) who found that teachers with little or no use of CBL techniques in their classroom also appeared unaware of sources of information on CBL. Their non-participation was due, at least in part, to ignorance rather than simply to rejection of this teaching strategy, and their comments suggest that they would have liked more information to be made available to them. These results are of course a call for more pre-service and in-service training of teachers. Opacic and Robert argue that such training should be selectively directed towards female teachers. The results of the study reported here, from a predominantly female sample, show that teachers will be largely receptive to such advice.

· The empirical studies presented here are equally encouraging. They show that children's classificatory ability can be enhanced by the use of open-ended computer packages. In particular they support a tool-use approach to the computer in the classroom, although moderate performance gains did occur with a more traditional tutoring strategies in the classroom. Specifically this tool-use appears to encourage the development of higher level cognitive skills, such as the ability to categorise and sort data, rather than influencing factual learning. These results are in line with subjective evidence reported in the case studies here, and by other workers such as Daiute (1985) and Rubin (1983).

Classroom computers can have notably desireable effects upon children's cognitive development. It has yet to be established how the benefits of this innovation should be introduced into our educational system.

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APPENDIX I

Eigenvalues for the Factor Analysis: Teacher Attitudes Survey

Factor	Eigenvalue	Percentage	Cum Percent
1	5.78	19.91	19.91
2	2.54	8.74	28.65
3	2.17	7.49	36.15
4	1.51	5.20	41.34
5	1.17	4.04	45.39
6	1.12	3.85	49.24
7	1.08	3.74	52.98
8	1.03	3.54	56.51
9	0.98	3.36	59.87
10	0.90	3.11	62.99
11	0.89	3.07	66.05
12	0.84	2.09	68.96
13	0.82	2.83	71.79
14	0.78	2.68	74.47
15	0.75	2.57	77.04
16	0.68	2.34	79.37
17	0.64	2.20	81.57
18	0.62	2.13	83.70
19	0.57	1.98	85.67
20	0.55	1.89	87.56
21	0.53	1.82	89.38
22	0.49	1.70	91.07
23	0.46	1.59	92.66
24	0.42	1.43	94.09
25	0.41	1.41	95.50
26	0.38	1.31	96.81
27	0.35	1.19	98.00
28	0.31	1.06	99.06
29	0.27	0.94	100.00

There are eight eigenvalues over 1.00

Analysis of Variance Summary Table: Experiment 2

Comparison of goodness-of-fit scores for subject's data organisations against pre-defined data organisations (Complex analysis).

source	sos	df	ve	F	df2	p	
A	6.3499	1	6.3499	.35	36	.55566	
B	785.2349	3	261.7450	50.15	108	.00000	***
AxB	20.8665	3	6.9555	1.33	108	.26757	

source /groups	sos	df	ve
S	646.0186	36	17.9450
SxB	563.6467	108	5.2190

Factor A: Age of subjects (third year children vs. fourth year children)

Factor B: Type of pre-defined data organisation (Lists, Hierarchies, Networks, Tables)

Analysis of Variance Summary Table: Experiment 3

Comparison of goodness-of-fit scores for subject's data organisations against pre-defined data organisations (Complex analysis).

source	sos	df	ve	F	df2	p	
A	47.8302	1	47.8302	3.16	50	.08151	
B	1623.3969	3	541.1323	116.55	150	.00000	***
AxB	19.2428	3	6.4143	1.38	150	.25068	

source /groups	sos	df	ve
S	756.6121	50	15.1322
SxB	696.4594	150	4.6431

Factor A: Age of subjects (third year children vs. fourth year children)

Factor B: Type of pre-defined data organisation (Lists, Hierarchies, Networks, Tables)

Analysis of Variance Summary Table: Experiment 4

Comparison of goodness-of-fit scores for subject's data organisations against pre-defined data organisations (Complex analysis).

source	sos	df	ve	F	df2	p	
A	.8030	1	.8030	.15	48	.69597	
B	9.5087	2	4.7544	3.15	96	.04741	*
AxB	1.6954	2	.8477	.56	96	.57236	

source /groups	sos	df	ve
S	249.4120	48	5.1961
SxB	144.9946	96	1.5104

Factor A: Age of subjects (third year children vs. fourth year children)

Factor B: Type of pre-defined data organisation (Hierarchies, Networks, Tables)

Analysis of Variance Summary Table: Experiments 2, 3, & 4

Comparison of goodness-of-fit scores for subject's data organisations against pre-defined data organisations, for three experiments (Complex analysis).

source	sos	df	ve	F	df2	p	
A	13817.3223	2	6908.6611	7.86	137	.00058	***
B	37759.4922	2	18879.7461	62.72	274	.00000	***
AxB	9103.3467	4	2275.8367	7.56	274	.00001	***

source /groups	sos	df	ve
S	120347.2031	137	878.4467
SxB	82474.4531	274	301.0016

Factor A: Experimental treatments (Expt. 2 vs. Expt. 3 vs. Expt. 4)

Factor B: Type of pre-defined data organisation (Hierarchies, Networks, Tables)

Analysis of Variance Summary Table: Experiment 5

Comparison of scores on the classification task before and after the experimental treatment, for four groups of subjects.

source	sos	df	ve	F	df2	p	
A	2.3120	1	2.3120	.15	36	.69627	
B	21.6320	1	21.6320	1.45	36	.23658	
C	34.3220	1	34.3220	9.07	36	.00474	**
AxB	.0320	1	.0320	.00	36	.96333	
AxC	1.8000	1	1.8000	.48	36	.49491	
BxC	24.2000	1	24.2000	6.39	36	.01599	*
AxBxC	2.1780	1	2.1780	.58	36	.45310	

source /groups	sos	df	ve
S	537.5261	36	14.9313
SxC	136.2900	36	3.7858
between S	561.5020	39	
within S	198.7900	40	

Factor A: Type of classification program (SEEK vs. FACTFILE)

Factor B: Teaching strategy (with vs. without the computer)

Factor C: Classification task scores (pre- vs. post-treatment)

Analyis of Variance Summary Table: Experiment 5

Knowledge acquisition test after the experimental treatment

source	sos	df	ve	F	df2	p
A	1.4083	1	1.4083	.67	36	.41730
B	.6750	1	.6750	.32	36	.57351
C	2.8500	2	1.4250	2.67	72	.07597
AxB	1.8750	1	1.8750	.90	36	.35006
AxC	.8167	2	.4083	.77	72	.46879
BxC	1.9500	2	.9750	1.83	72	.16810
AxBxC	.6500	2	.3250	.61	72	.54647

source /groups	sos	df	ve
S	75.3000	36	2.0917
SxC	38.4000	72	.5333
between S	79.2583	39	
within S	44.6667	80	

Factor A: Type of classification program (SEEK vs. FACTFILE)

Factor B: Teaching strategy (with vs. without the computer)

Factor C: Knowledge acquisition task scores (correct responses against number of answers available)

Analysis of Variance Summary Table: Experiment 5

Knowledge acquisition task after the experimental treatment

source	sos	df	ve	F	df2	p	
A	1.6333	1	1.6333	.79	36	.38033	
B	.8333	1	.8333	.40	36	.52981	
C	8.8667	2	4.4333	6.56	72	.00242	**
AxB	1.6333	1	1.6333	.79	36	.38033	
AxC	1.2667	2	.6333	.94	72	.39653	
BxC	.4667	2	.2333	.35	72	.70924	
AxBxC	2.0667	2	1.0333	1.53	72	.22376	

source /groups	sos	df	ve
S	74.5333	36	2.0704
SxC	48.6667	72	.6759
between S	78.6333	39	
within S	61.3333	80	

Factor A: Type of classification program (SEEK vs. FACTFILE)

Factor B: Teaching strategy (with vs. without the computer)

Factor C: Number of questions asked on three levels of complexity of attribute-combination

Analysis of Variance Summary Table: Experiment 6

Comparison of scores on the classification task before and after the experimental treatment, for two groups of subjects.

source	sos	df	ve	F	df2	p	
A	.2133	1	.2133	.02	22	.88868	
B	3.7408	1	3.7408	6.29	22	.02002	*
AxB	.9633	1	.9633	1.62	22	.21644	

source /groups	sos	df	ve
S	234.0759	22	10.6398
SxB	13.0858	22	.5948
between S	234.2892	23	
within S	17.7900	24	

Factor A: Teaching strategy (with vs. without the computer)

Factor B: Classification task scores (pre- vs. post-treatment)

Analysis of Variance Summary Table: Experiment 7

Comparison of scores on the classification task before and after the experimental treatment, for two groups of subjects.

source	sos	df	ve	F	df2	p	
A	.9020	1	.9020	.60	20	.44602	
B	5.6020	1	5.6020	19.45	20	.00027	***
AxB	.9020	1	.9020	3.13	20	.09203	

source /groups	sos	df	ve
S	29.8518	20	1.4926
SxB	5.7609	20	.2880
between S	30.7537	21	
within S	12.2650	22	

Factor A: Teaching strategy (with vs. without the computer)

Factor B: Classification task scores (pre- vs. post-treatment)

Analysis of Variance Summary Table: Experiments 5, 6 & 7

Comparison of classification scores before and after the experimental treatment, in three experiments.

source	sos	df	ve	F	df2	p	
A	23.2286	2	11.6143	1.48	60	.23536	
B	.0784	1	.0784	.01	60	.92064	
C	18.1899	1	18.1899	14.26	60	.00037	***
AxB	7.9493	2	3.9746	.51	60	.60474	
AxC	3.0738	2	1.5369	1.21	60	.30682	
BxC	18.7345	1	18.7345	14.69	60	.00031	***
AxBxC	5.9821	2	2.9911	2.35	60	.10455	

source /groups	sos	df	ve
S	470.1829	60	7.8364
SxC	76.5212	60	1.2754

Factor A: The three experimental treatments (Expt. 5 vs. Expt. 6 vs. Expt. 7)

Factor B: Teaching strategy (with vs. without the computer)

Factor C: Classification task scores (pre- vs. post-treatment)