The Effects of Microcomputers in Chemistry Classrooms

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The Effects of Microcomputers in Chemistry Classrooms

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Abstract

The principle aim of this study is the delineation of the changes which occur in the classroom when Computer Assisted Learning (CAL) techniques are used. The study is mainly concerned with changes in the chemistry classroom, although some examples have also been drawn from other areas of science education.

A number of particular teacher-class groupings were observed over several lessons, both with and without the use of CAL. A Systematic Classroom Analysis Notation (SCAN) was used to record the observations and to provide a detailed record for analysis of the classroom phemomena. The recorded "SCANs" were then examined for patterns which would reveal differences in lesson structure and in teacher and pupil behaviour which might be attributed to the use of CAL. Some of the lessons were recorded on video, to allow some triangulation of the classroom observations and their interpretation.

The effects of the introduction of CAL into the traditional lesson forms - 'Theory' and 'Practical' - are considered in detail and results are presented which suggest that the use of CAL does indeed bring about changes in the classroom, both in organisation and management and in teaching and learning styles.

The causes of these changes are also examined so as to elucidate good classroom practice in the use of CAL and to reveal any possible implications for CAL developers.

By facilitating direct pupil control of their own access to the knowledge-base, CAL can support role changes amongst teachers and pupils of a kind which would widely be regarded as beneficial. CAL is seen to be most effective when it is used in group-based, open-ended situations where it encourages pupils to undertake independent, exploratory learning activities and where it supports the teacher in the role of facilitator, advisor and group-member.

The precis sets out the principal aim of this research as the delineation of the changes which occur in classroom life when microcomputers are used. There have, of course, been many studies of classroom life: some on a large-scale, others by single researchers; some using quantitative methodologies, others using qualitative ones. The literature relating to such studies, which is reviewed in the next chapter, is seen as providing a background to the decisions taken in the planning and execution of this current study.

The literature survey revealed a wealth of different approaches to the study of classroom life, each with its own strengths and weaknesses. It was felt that an eclectic approach, which took on-board the strong points of the various methodologies as appropriate, would be best suited to this research.

This early decision to take a mid-line approach, between what are often seen as opposing methodologies, was seen as having a beneficial effect on the study as a whole: it would allow an open ended approach to the study of classroom life, yet give some structure to the data collected. Such an approach would allow an observer to approach a classroom with as few pre-determined categories of observations and outcomes as possible: it would leave him open to respond to the unexpected and to follow lines of enquiry as they arose. However, recording the observations in a systematic manner would enable, for example, direct comparisons to be made between different lessons with the same teacher/class combination or between the use by different teachers of the same program.

Many observation schedules have been developed to systematize the recording of classroom observations. On examination, however, they appeared to be too prescriptive or to concentrate too much on one particular aspect of classroom life. Because the use of CAL in the classroom was so new, its effects were likely to be unpredictable: there was no received body of knowledge on which to base predictions. A more flexible, open-ended system of recording observations was felt to be necessary.

A Systematic Classroom Analysis Notation - SCAN (Beeby, Burkhardt et al. 1979) was known to be under development at Nottingham University and it was felt that this might provide a suitable medium for the recording of classroom observations in this study. In particular, it appeared to offer a middle line between the wholly descriptive, qualitative approach and the analytic, tightly controlled, quantitative approach. The use of SCAN will be discussed in detail in Chapter 3.

The extent to which the results of a study can be generalised is always problematic in any educational enquiry. This uncertainty is especially acute in the study of educational innovation. The teachers taking part in this study were a sample of those who had already used, or were about to use, CAL: they could not be regarded as completely typical, they were innovators. While such constraints may be unavoidable, they need not invalidate the findings of a study. The findings would be most likely to be generalisable if the teachers represented as wide a range as possible in their experience with CAL and their teaching style. It was felt that they should also be teaching in schools whose intakes represented a range of different demographies.

Initially, contacts were established with a large number of schools - through questionnaires, through personal contacts and with the help of colleagues - and informal visits were arranged. During talks with the various teachers visited, a clear picture of (their view of) their school usually emerged. Where staff expressed an interest in the use of CAL in chemistry teaching, a number of follow-up visits were arranged and lessons were observed. These informal, unstructured observations revealed, prima facie, a range of differences in teaching styles: some teachers generally adopted a formal, didactic approach; some showed more interest in group work; some encouraged the pupils to do practical work; some gave notes and set imitative problems; some used 'open-ended', investigative work; while with others even the practical work was tightly closed.

Following these initial observations, it was possible to select a number of teachers who, between them, represented a range of teaching styles in a range of schools. Discussions with this smaller group of teachers enabled software to be selected which they could use in their classrooms without disturbing the planned order of topics to be taught. This helped to minimise the changes to the setting caused by the act of research.

It was felt to be unwise to rely on a single source of data - especially as only one observer/researcher would be involved. Secondary data sources would be needed by which the adequacy and replicability of the SCAN records could be judged. Sound and/or video recordings were made, therefore, of the lessons observed and transcripts of the dialogues were compared with the SCAN records. It was found to be possible to identify particular sections of the SCAN with particular passages in the transcripts and to match the flow of events recorded in the SCAN against that in the recordings. The success of this triangulation of techniques provided good support for the interpretation of the SCAN records reported in this study.

As well as selecting an appropriate research technique, it was also necessary to have some idea of the level of provision generally available in schools and the extent of use that interested teachers made of the micro. Two questionnaires were developed and distributed: one to the appropriate advisor in each LEA, to assess the provision being made for schools; and one to the 'Head of Chemistry' in each of 192 secondary schools to assess the use of micros in the teaching of chemistry. This second questionnaire also established a point of contact with those departments interested in the use of CAL and so provided a basis on which entry to schools to observe lessons could be negotiated.

Obviously, in such a rapidly changing area, the data generated by the questionnaires would soon become obsolete and, while the information gained provided a necessary background to the study, the analysis of the questionnaire returns was felt to be outside the main thrust of the research. This analysis is, therefore, dealt with in Appendix 1.

The series of observations undertaken in this study revealed a number of important changes brought about by the use of CAL, both in teaching and learning styles and in the roles adopted by teachers and pupils. Teachers were less didactic and pupils took on a more active role in structuring their own learning experience. This, inevitably, involved the pupils in using higher level skills than would be expected to arise in the teacher-exposition role which dominated so many non-CAL-based lessons.

The use of a micro was seen to move the focus of classroom activity away from the teacher, allowing pupils to pursue independent lines of enquiry and, sometimes, allowing teacher and pupil to share a common learning/investigating experience. This was most noticeable where the program was open-ended and where the precise results were not easily predicted by teacher or pupil.

In many cases, both teacher and pupils appeared to allot a separate, independent role to the micro: the micro, not the teacher, was seen as the source of knowledge on which an investigation could be based; the micro could both set the task and enable the pupils to monitor their own progress. It had, in effect, become a 'third person' in what would otherwise be a two-part, teacher-pupil relationship. It is the existence of this 'third person' which enabled role changes to occur.

The presence of a 'third person' in the classroom, to whom the pupils can turn for knowledge and guidance, is almost certain to change the normal teacher-pupil relationship: at times the most active relationship appears to be that between pupils and micro, with the teacher as the 'third person'. Such marked role-changes cannot but affect all aspects of classroom life and it is with this ability of the micro, to change the teaching and learning experience, that this thesis is concerned.

Chapter Two

The Literature Survey

At the time this study began in 1981, Edmonds (Edmonds, 1980) and Atherton (Atherton, 1979) had reported that the costs of microcomputers and their associated hardware had fallen dramatically while, at the same time, the sophistication of the 'software' and 'firmware' available had increased. By this stage, it had become possible for an inexpensive 'micro' to draw 'high resolution pictures' on a v.d.u. and to output these to a printer or store them on a disk. Software was becoming available which made the entire system interactive, in that the output given was in direct response to the user's input and so was not limited to a small number of fixed diagrams and examples, such as might be the case in, say, a text-book or a film.

The falling cost in computing power meant that 'micros' were becoming available in schools in ever-increasing numbers. The initiative taken by the DoI in providing half the cost of a microcomputer for every school, together with the tremendous public interest shown in the development of "personal" computers, were major factors in influencing the extremely rapid growth in hardware provision which occurred at this time. This growth in hardware completely outstripped the growth in software provision and, in many ways, one was reminded of the early description of the laser as "a tool looking for a job".

The Microelectronics Education Programme (MEP) supported both software development and in-service teacher training courses concerned with the applications of the microcomputer in schools, and the Schools Council and various educational publishing houses were also concerned with the production of software. However, the number of good packages suitable for use in schools was still quite small and the software which had become available had often undergone little evaluation other than to check that the programs functioned correctly: there simply had not been time to study the effects of the use of Computer Assisted Learning on classroom management and on the interactions occurring within the classroom.

It was against this background that this study was initiated, with the aim of elucidating the effects of Computer Assisted Learning in the classroom.

CAL and CAI

Computer Assisted Learning (CAL) in the U.K. seemed to have acquired a different emphasis than in the U.S.A., where it was usually called Computer Aided Instruction (CAI): the latter tending to be almost entirely in the programmed instruction/tutorial style (Hinton, 1977). CAL was seen as placing the emphasis much more on "the student as the subject of education .... (rather than) .... the subject matter as the object of learning" (MacDonald et al, 1977(a)). Laurillard (1978) said of CAL packages, "... (they) enrich learning and promote intuitive understanding". Indeed, in nearly all cases in this country, computers were seen in education as providing an enrichment medium rather than an initial teaching medium. It was in this enrichment mode that CAL was felt to hold most promise in schools in the U.K., whereas the CAI 'tutorial' mode was seen as more suited to industrial and military training, where task-specific objectives can be applied. More recently, Maddison (Maddison, 1983) and others have referred to a wide range of acronyms related to the use of computers in education - CAL, CAI, CBL, CBE, CBI, CML, etc - the exact meaning of which varies from one author to another. For simplicity, this study will use the one term, 'CAL' - Computer Assisted Learning, to cover those occasions when a teacher uses a microcomputer in an educational context with one or more pupils.

Developments in CAL

In 1979, Summers felt that "... good CAL packages utilising the full potential of microcomputer extended BASIC, (especially graphics) have not yet been developed". Indeed, most of the commercial packages then available, such as those produced by the Schools Council Computers in the Curriculum Project, had been written for use on mainframe computers connected to a teletype terminal and so the use of graphics was very limited because of the typewriter format this system imposed.

In the further and higher education sectors, where v.d.u. access to a mainframe or mini computer was feasible, increasing interest was being shown in the use of graphics in CAL packages (McKenzie, 1976; Laurillard, 1976; Crease, 1977; Summers, 1979) and, with the development of more sophisticated micros, interest in the use of graphics on these machines grew rapidly (Ben-Zion, 1980).

By 1981, work had begun on rewriting much of the early Chelsea Science Simulation and Schools Council Computers in the Curriculum project materials, to make use of the extended facilities which had become available and the major educational publishing houses were also showing increasing interest in CAL packages. Virtually all of the units being designed at this stage made some use of the 'graphics' and 'paging' facilities of the microcomputer and the possible uses of colour were being examined. Later units, such as 'Bonding', 'Polymers' and 'Periodicity' (Chatterton and McCormick, 1986), were to make use of still other facilities, such as the ability to store and retrieve information on disc, simple animation and sound. Of at least equal importance, the 'user interface' was considerably simplified, with relatively few 'key-presses' needed to choose options and/or values.

In addition to the involvement of these professional bodies, teachers, both individually and in small groups, were beginning to write programs for use in schools. However, there were several constraints which restricted the usefulness of this kind of ad hoc arrangement. Firstly, there seemed to be no easy way of ensuring a minimum duplication of effort - to avoid very similar packages being produced by different individuals or groups. Secondly, the various dialects of BASIC in use made inter-machine transfer of programs problematic (sometimes even between different models of the same make). Thirdly, the 'unstructured nature of BASIC' made it difficult to follow the logic of someone else's program (Atherton, 1979) and so the adaptation of a program to one's own needs could be difficult.

Some attempts were being made to overcome these difficulties: both MUSE (Microcomputer Users in Secondary Education) and the Chelsea College Computers in the Curriculum project (CCCC) attempted to use a (different) standard subset of BASIC. MUSE published a set of standards for their subset and for their style of program construction (Sweeton, C. 1980)

However, the rapid developments taking place in the capabilities of microcomputers and the increasing variety appearing in the market-place, each with its own dialect of Basic, meant that these early attempts were fairly short-lived or restricted in their application.

The Computers in the Curriculum project went on to develop a set of standard subroutines for each of the major micro's in the education market. The subroutines themselves were machine-specific, but, because they used standard structures, a single program calling these routines could be written and added to the subroutine 'library' for each type of machine. In this way, once a program had been designed, versions could be produced for a range of micro s with the minimum of compatability problems (CCCC Library, 1984). In addition to being used with the their own wide range of CAL programs, this library has found some acceptance outside the originating project.

Evaluation of CAL in Higher Education

In the U.K., CAL was first used in the universities and polytechnics in the 1970's with such programmes as NDPCAL and CALCHEM, and various studies were undertaken to evaluate the effect of these programmes on student progress and motivation (MacDonald, 1977(a), 1977(b), 1978; Miles 1977, Laurillard 1978).

MacDonald (MacDonald et al, 1977(a)) suggested a set of educational paradigms for CAL and discussed how these map into a typology of five student - CAL interactions. His suggested paradigms are:

1) Instructional - rather like the American CAI aimed at 'mastery of content' and with the curriculum emphasis on the 'subject matter as the object of learning'.

2) Revelatory - in which 'discovery ' and 'intuition' are aimed at and the curriculum emphasis is on the 'student as the subject of education'.

3) Conjectural - where 'articulation', 'manipulation of ideas' and 'hypothesis testing' are the primary concepts; the curriculum emphasis is on 'understanding' and 'active knowledge'.

He also suggested a further 'as yet unarticulated' paradigm:

4) Emancipatory - in which CAL reduces 'inauthentic student labour', by removing from the student the need to do repetitive and/or thoroughly understood calculations or operations.

This is not to suggest that 'authentic labour' will replace what was removed and it would seem (to me) that the removal of all 'inauthentic labour' could lead to insecurity in the student by removing what he may normally see as the main point of 'doing', for example, the gas laws or calculations and chemical equations. Indeed, MacDonald (ibid) stressed that these paradigms are 'aspirations' and that how they could be achieved was 'a separate question'. Nevertheless, they would seem to form a good starting-point for the analysis of the curriculum content of CAL packages.

The interaction typology seeks to make explicit the learning processes that may be promoted by student-CAL interaction. The typology may be summarised as follows:

A) Recognition - the student simply indicates whether or not information presented in the form of a question or incomplete statement has been presented before.

B) Recall - the student is required to recognise information, but understanding is not necessary. The student reproduces information verbatim or 'transformed verbatim'.

C) Reconstructive Understanding or Comprehension -

this can range from elementary comprehension to quite subtle judgements and the questions asked do not depend on the superficial features of the information presented as do A) and B). The student is engaged in 'meaningful operations' on the content presented, i.e. reconstruction of statements, concepts and principles.

D) Global Reconstruction or Intuitive Understanding -

this often involves the student in prolonged activity, so that he/she 'gets a feel' for an idea and develops quite sophisticated pattern-recognition skills or a sense of strategy.

E) Constructive Understanding -

this is an extremely open-ended situation in which the student is, from his own viewpoint, creating new knowledge and appears to be doing research. This will be more or less closely inter-linked with the other four types of interaction.

Figure 2.1 (below) shows the possible relationships between the paradigms and the interaction types, i.e. between the curriculum and the learning process in CAL.

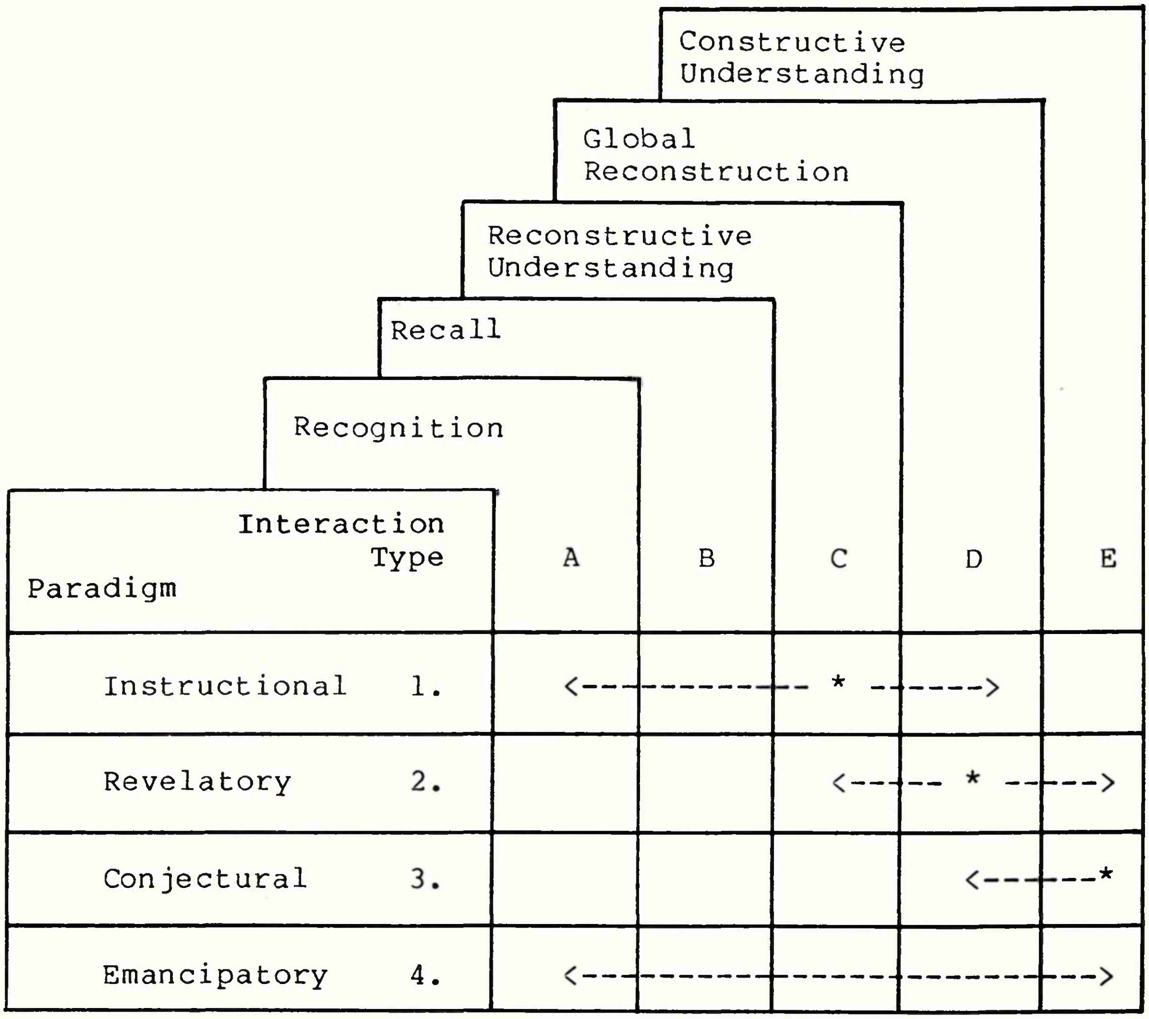


Figure 2.1

Possible Relations between Paradigms and Interaction Types

(after MacDonald, B. et al. 1977(a))

Some Implications for CAL in Schools

With the evaluation of CAL in schools still in its infancy, there are no reports yet published which delineate a similar structure of paradigm and interaction typologies at the school level. However, it seems likely that those suggested above, although arising from studies of CAL at the undergraduate level, could be applied equally well to CAL at school level. Certainly, pattern-recognition and open-ended, discovery-learning techniques are widely used in primary schools and are seen as important aspects of the secondary school science curriculum. However, such schema are simply descriptive and may be of limited value unless they can be applied to the development/evaluation cycle in such a way as to improve the program designers' understanding of classroom events.

Implications for the Evaluation Methodology

Apart from the problems of evaluating the usefulness of these paradigms and typology and the extent to which particular CAL packages fit them, methodological problems arise from the nature of the paradigms and typology themselves. For instance, the students may be constrained to follow a particular path designed by the developer in an 'adaptive tutorial' package - even when the design is branched. In the revelatory paradigm, the students are exposed to other students working on the same package and may, therefore, gain foreknowledge of suitable responses. There are various general problems also, in addition to those specifically related to the paradigms, such as understanding the difficulty or subtlety of ideas, the reliability (or otherwise) of the machine and the complexity of the student/machine interface.

All these factors, together with the personalities and backgrounds of the students and teachers, may affect the final outcomes of any CAL package. With such a range of complex, interacting variables, the evaluation of CAL becomes very problematic. Indeed, with the small groups and restricted timescale normally available, properly-controlled quantitative evaluation becomes virtually impossible and, over the past few years, increasing interest has arisen in the usefulness of more qualitative forms of evaluation.

A wealth of literature exists on the pro s and con s of the various forms of evaluation and several models for qualitative evaluation have been proposed (Bynner, 1980; Cronbach 1978, 1975; Smith and Fraser, 1980; Wilson, 1977; Smith, 1978; Stake, 1978, 1975(a); Parlett and Dearden, 1977; Eisner, 1977; Guba, 1978; Hamilton et al, 1977; Campbell and Stanley, 1966). In all these, the major emphasis would seem to be on observation of the package in use followed by unstructured interviews with the students and, possibly, with the staff. MacDonald (1977(b)) also favoured such an approach for the UNCAL evaluation of NDPCAL "... UNCAL itself prefers to work largely through unstructured interviews and observations towards integrated portrayals ...".

At the other extreme, Campbell and Stanley (1966) favour a much more 'rigorous', more 'quantitative' approach, saying "Internal validity is the sine qua non of causal inference". More recently, Campbell has moved towards the middle ground and Bynner (1980) says "He (Campbell) now advocates full exploitation of the narrative records of participants in the programs to run alongside experimental procedures". Bynner (ibid) goes on to say that "Evaluators need to check their quantitative findings continually against the perceptions of participants and when the two fail to tally the quantitative findings are more likely to be suspect".

There also seems to be a growing awareness of the need for evaluations to be relevant, in the sense that they should help the decision-makers (CAL-designers and those in a position to implement the use of CAL) to make sound, fruitful decisions. In this sense, external validity is seen to be important, perhaps more so than a rigorous internal validity. External validity is, however, a difficult concept here, as the decision-makers' perceived interests and needs change rapidly as the technology involved in CAL advances.

As qualitative methodologies are seen as underpinning the experimental design developed for this project, the nature of qualitative data and its collection and analysis will now be discussed in detail.

The Nature of Qualitative Data

In order to discuss the collection and analysis of qualitative data, it is necessary, first of all, to describe what constitutes 'qualitative' data and how this differs from 'quantitative' data. Patton (1980 p.22) says that,

> "Qualitative data consists of **detailed descriptions** of situation, events, people, interactions and observed behaviours; **direct quotations** from people about their experiences, attitudes, beliefs and thoughts; and excerpts or entire passages from documents, correspondence, records and case histories."
> (emphasis in the original)

All of these constitute raw data and are collected without attempting to fit them into predetermined classes as a typical questionnaire or test does. This type of data contrasts starkly with typical quantitative data. Qualitative data are variable in content, not restricted to a 1-to-5 scale or a good-to-bad differential; the data are unformatted, being neither standardised nor systematic; the responses are longer, more detailed and open-ended; and they should illuminate the perspectives of the respondents rather than "predetermining those points of view through prior selection of questionnaire categories" (Patton 1980 p.22). Such data will, undoubtedly, be more difficult to analyse than quantitative data. However, they can provide insights into the problem being researched in a way which quantitative data cannot. The qualitative approach is essentially holistic and places the event being studied into its context. It allows data to be gathered on any number of aspects of the setting and allows unforseen outcomes to be recorded or probed further. The approach is also inductive in that it allows the analysis of the situation, without attempting to impose pre-ordinate expectations on the research setting. This again contrasts with the traditional research paradigm which is both particularistic, being concerned with isolating and controlling individual variables, and deductive, in that the important variables and the relationships between them are postulated before data are collected. Patton (1980 p.41) says,

> "The strategy in qualitative designs is to allow the important dimensions to emerge from the analysis of the cases under study **without presupposing in advance what those important dimensions will be."**
> (sic: italics in the original)

Qualitative Research Styles

Qualitative designs are also said to be 'naturalistic', that is the researcher does not attempt to impose a predetermined course of events, but rather attempts to investigate the phenomena "within and in relation to their naturally occurring context" (Willems and Rausch 1969 p.3.). Guba(1978) also discusses 'naturalistic inquiry' in terms of minimising investigator-manipulation of the research setting and says that it is a "discovery-oriented approach". In practice, the adoption of naturalistic inquiry and the holistic-inductive analysis of data is a matter of degree and Guba (1978), Patton (1980) and others favour an eclectic approach in which the investigator begins the research completely open to whatever emerges from the data and progressively focusses on elucidating and verifying the patterns of interest which appear from the data: an approach which gradually becomes more deductive in style.

Smith (Smith, N.L. 1978 p.17) would also seem to accept the need for an eclectic approach when he says,

> "Naturalistic descriptions give us greater certainty in our understanding of the nature of an educational process than randomized, controlled experiments do, but less certainty in our knowledge of the strength of a particular effect....."

Smith and Fraser (1980), Bynner (1980), Cronbach (1978, 1975) and Macdonald (1977(b)) all favour using a mixture of qualitative and quantitative methodologies.

Smith and Fraser (ibid) say,

> "the usefulness of an evaluation often can be enhanced by the use of multiple methods and the combination of information obtained from different sources".

Cronbach (1978) says that such an approach "always makes sense" and that:

> "The balance between styles may vary from one sub-question to the next and may well shift in either direction as the evaluation proceeds."

Finally, a further quote from Patton (1980 p.114) highlights what may prove to be an important practical advantage of using qualitative methodology.

> "It is possible to convert detailed, qualitative descriptions into quantitative scales for the purpose of statistical analysis. It is not possible, however, to ..... convert purely quantitative measures into detailed, qualitative descriptions."

While a fully detailed analysis of the relative strengths and weaknesses of quantitative and qualitative approaches would be beyond the scope of this literature survey, the following sections attempt to highlight the more important qualitative methodologies which could be used in this study, contrasting qualitative and quantitative approaches where appropriate.

Methods of Data Collection

In considering ways of collecting qualitative data, two principle methods predominate: observation and interview. Each of these can be approached in a variety of ways: observation can be covert or overt, obtrusive or unobtrusive and the observer can range from being completely detached to being a full participant; interview styles can vary from the highly structured to the completely open-ended or conversational. Questionnaires are not normally used in qualitative designs, largely because of the difficulty of interpreting the replies to free response, open-ended questions; it is usually impracticable to check the meaning with the respondent. McKenzie (1977 p.218) says,

> "Questionnaires have proved helpful but there is no substitute for the time-consuming method of direct observation ..... followed by a brief interview."

OBSERVATION

Possible Problems and Solutions

In any attempt to observe the educational process, it is "impossible psychologically and physiologically to observe everything [and] the researcher must necessarily be selective and focus his observations" (McNamara 1980 p.114). However, it is important to enter the classroom with as few predetermined conceptions as possible and to remain open to the influences at work within the situation. The initial visits should "illuminate" the important influences and the 'focussing' should be progressive rather than immediate. In practice, the observer can never be neutral, nor can the observations be completely exhaustive and, in interpreting the observations, the researcher must try to remain aware of his own prejudices.

McNamara (ibid) is critical of unstructured observation, both from a methodological standpoint and from his view of the susceptibility of unstructured observation to the biases of the observer. Furthermore, as covert observation is rarely possible (and probably ethically undesirable) in a naturalistic educational setting, the behaviour of both pupils and teachers is, he feels, liable to modification by the presence and activities of the observer.

These objections can, I feel, be overcome in practice. The effects of observer bias may be reduced in several ways:

- multiple observers could be used so that the biases of a single observer have much less effect;
- a panel of 'judges' or 'experts' could be used to examine the methods used to collect data, the data itself and the analysis and interpretation of the data;
- a single observer could observe many similar situations and compare his findings with those of others in the field with the <u>conscious intention</u> of revealing his own biases.

Similarly, the effects which the observer has on the situation can be reduced by careful negotiation of his entry into the setting and by repeated observation (Lofland, 1971; Patton 1980). The observer should avoid making either staff or pupils feel threatened by his presence: this is probably best done by being candid about the reasons for the observation and making it clear that the participants are <u>not</u>, in any sense, being tested. In schools, the relationship of the teacher to the head and to other members of staff may be important in determining his/her initial response. The teachers involved should not feel that the observer has been 'forced on them' by the headteacher or that the evaluation could be used to adversely affect their careers. In practice, it may be better to get the teacher's informal consent before approaching the head for formal consent to work within the school.

The unavoidable behaviour modifications introduced by the presence of the observer diminish rapidly with time - especially the modifications of the children's behaviour. The children will obviously be curious about any 'stranger' in the classroom and the observer may find talking informally with the pupils about his work in the classroom helps to satisfy this natural curiosity. Familiarity certainly helps to breed a lack of interest, on the part of the pupils, in someone who regularly sits quietly making notes at the back of the classroom: the observer rapidly becomes part of the normal environment.

Advantages of Observation

Direct observation is seen by many researchers as having many advantages over other forms of research (Lofland 1971; McKenzie 1977; Patton 1980; Smith, N.L. 1978; Webb et al. 1966). These advantages may be summarised as follows:

- Direct observations enable the context of events to be understood - essential to a holistic perspective.
- First-hand experience of the events allows the researcher to be inductive and to avoid preconceptions, whether his own or others.
- The researcher has the opportunity to see things which may not be consciously noticed by the staff or pupils and which would not, therefore, be revealed by an interview or questionnaire. This is probably most particularly true of events which have become routine to the participants.
- The researcher may learn things which pupils or staff may be unwilling to talk about in an interview.
- The researcher can "move beyond the selective perceptions of others" (Patton 1980 p.125). The interviewees necessarily report perceptions of events - indeed this is the crux in interviewing - whereas the observer can observe what actually happens in the situation. However, the observer, too, has his own

perceptions and these can form important additional data. Scriven (1972 (a), p.99) said, "for the social scientists to refuse to treat their own behaviour as data from which one can learn is really tragic."

- Direct contact with and experience of the events being studied increases the observers' depth of understanding and so aids interpretation.

> "Because he sees and hears the people ..... in many situations ..... [not] just in an isolated and formal interview, he builds an ever growing fund of impressions ..... which give him [the researcher] an extensive data base for the interpretation and analytic use of any particular datum."
> (Becker and Geer 1970 p.32)

Such unstructured observations cannot be a 'once and for all' occurrence. Much of their value relies on repeated observations so that impressions gained at an early stage can be increasingly refined and substantiated, or rejected, by later observations.

Taking Field Notes

The essential purpose of observation is to enable one to describe the people who participate; the events, activities and interactions that occur in a given setting; and the meanings to those people of the events, activities and interactions which occurred. The accurate recording of observations is, therefore, essential. In most cases, this involves the making of 'field notes' and Lofland (1971 p.102) says:

> "Aside from getting along in the setting the fundamental concrete task of the observer is the taking of field notes. Whether or not he performs this task is perhaps the most important determinant of later bringing off a qualitative analysis. Field notes provide the observer's raison d'etre. If he is not doing them he might as well not be in the setting."

However, the observer must be careful to make the notes in such a way as not to disturb those he is observing nor to detract from his own observations. This normally necessitates the notes being taken in a much abbreviated form, which should be expanded as soon as possible after the observation, while the experience is still fresh in the observer's mind. It will then be possible to explain that which appears cryptic in the notes and to add detail which may not have been included at the time. Lofland (1971 p.104) says that, in writing-up notes, one should ".... expect and plan to spend as much time in writing notes as one spent observing." This clarification and expansion of the notes immediately after the event could be done much more easily and quickly by using a tape-recorder. However, dictation is itself a skill which "takes practice, effort and critical review of early attempts". (Patton 1980 p.166). Needless to say, dictating notes into a microphone during a lesson would, almost certainly, be too obtrusive - certainly much more so than writing notes.

Observation Schedules

There have been many attempts to formalise observations by the production of a checklist of types or categories of events according to which the observed events can be classified. Simon and Boyer (1968, 1970) published several collections of articles documenting 118 different systems for interaction analysis including: verbal and non-verbal, systems for specific subjects (e.g. 'science' or 'modern languages'), systems using sound or video recording and systems using one or more observers in the classroom recording categories against time.

These checklists or schedules are themselves based upon and refined by repeated observations; they are, however, generally aimed at observing particular types of behaviour. Even then, their need to be generalised, to cover observations of a given type of behaviour in many different settings, can limit their usefulness in any one setting, especially where the setting is innovatory. One example of a 'checklist' or 'schedule' is "The Science Teaching Observation Schedule" (Eggleston, Galton and Jones 1975), which was designed to classify verbal interactions between teachers and pupils and between one pupil and another. Some 23 categories of interaction are used and, for convenience, the lesson is divided into consecutive three-minute slices (0-3, 3-6, 6-9, etc.). The types of verbal interaction are then recorded in a category/time matrix. In common with most approaches of this type, the schedule suffers from many restrictions and limitations. It is restricted to verbal interactions in science lessons - many of the categories will not apply even to mathematics. The data is limited in that the detailed order of interactions is not recorded, merely the broad movement of interactions through a lesson. The actual verbal activity is not recorded, neither are mannerisms nor attitudes, and the observer must make 'instant' decisions as to which category a specific interaction belongs. Moreover 'non-work' activity is completely ignored, yet peripheral activities often give good clues to what is really happening in the classroom.

The most effective observation technique may be a combination of methods: beginning with completely unstructured "illuminative" observation; then, progressively focussing on major isssues; and finally, producing an observation schedule which, at the least, would serve to highlight major features likely to arise in the observation.

Systematic Classroom Analysis Notation

The Systematic Classroom Analysis Notation (SCAN) is a method of making detailed recordings of some of the essential features of a lesson. It was developed originally (Beeby, Burkhardt and Fraser, 1979) to provide feedback in the development of new curricular material associated with the ITMA project (ITMA Newsletters 1 and 2, 1979). At first sight, SCAN seems closely related to some of the observation schedules, in that it provides a relatively easy method of recording the events occurring in a lesson. However, it is not prescriptive: it does not attempt to impose a preordinate structure to the lesson and the ease with which "unanticipated" events can be recorded allows it to be used as a "shorthand" form of the "field notes" discussed earlier. Such flexibility of response is seen as being of prime importance when investigating a novel situation such as the introduction of CAL into the classroom. A full discussion of the use of SCAN will be given in Chapter 3.

Sensitizing Concepts

It is widely recognised that eye-witness accounts of accidents or crimes are unreliable - witnesses of the same event may produce widely different accounts of what happened - and, if this 'unreliability' is to be avoided, then the observer must be trained to observe and record and must be prepared to observe at the moment the event occurs. To aid the observation of relevant material, the idea of "sensitizing concepts" (Denzin 1978 p.9, Patton 1980 p.137) is often used. Sensitizing concepts provide a basic framework, which highlights the importance of certain kinds of provision, events, activities and behaviours, rather than being prescribed categories or operationalised variables. Examples of such concepts could include 'the physical environment', 'the social environment', 'classroom activities'. Each of these would normally be broken down into a number of other sensitizing concepts. 'Social environment' could, for example, be broken down into 'patterns of interaction', 'frequency of interaction', 'direction of communication patterns', etc. The actual concepts used depend on the observer and what he is to observe. They form a guideline for his observation and are not prescriptive, as an observation schedule or category system would be, but may be modified by the observer's experiences. Denzin (1978 p.9) says the observer

> "..... moves from sensitizing concepts to the immediate world of social experience and permits that world to shape and modify his conceptual framework."

Observing Classroom Interactions

In observing the teaching and learning process in the classrom, the researcher is necessarily concerned with the ways in which the teacher and pupils interact with each other and with the ways in which these interactions are ordered. The classroom setting, however, is one which is familiar to all in our culture and Atkinson (1981) says that this very familiarity can be " ... a particular problem when working with interactional materials from natural occasions." and that observers should try to suspend their " ... own, commonsense, culturally given assumptions."

The process of distancing oneself from the data, to view it as new and 'anthropologically strange', can be easier if a permanent recording is available. Recording and transcribing of classroom events will not, of itself, produce the necessary degree of 'estrangement', but the "slow reading" (ibid) which transcription enforces does encourage the right approach. Atkinson (ibid) also notes that "records of actual interactions look awfully 'boring' and lacking in 'news'" to the novice. Repeated re-reading of the transcripts will, however, allow the researcher to examine the social organisation of the talk, how the events arose and what their consequences were, and to place particular sequences of events in a broader, more meaningful, framework.

Barnes and Todd (1981) discuss the strategies they used in attempting to "describe the talk of small groups of children in ways which would distinguish successful engagement with the learning tasks they had been set". They used two distinct research paradigms, in different stages of their study, referred to as "Participatory" and "Experimental". These were, essentially, matched by the 'qualitative' and 'quantitative' terminology of this study. In describing the pupils' responses to being tape-recorded (ibid), they said:

> "We surmise that no groups were ever entirely unaware ... [although] during the Participatory Phase [they] seem to have forgotten briefly. ....
> For the Experimental groups, we never ceased to be threatening outsiders; only the Participatory groups could perceive us as unthreatening."

This would suggest that, in appropriate circumstances, the actual act of recording need not prevent naturalistic responses being obtained from the pupils: while the observer must still beware of so disturbing the setting that the observations are no longer representative of the normal classroom, his presence need not be a major factor in the pupils' responses.

The observer should also beware of simplistic interpretations of the pupils' responses. The teacher and the observer are not the only influences on the pupil:

peer groups inside and outside the classroom have a major part to play in determining pupils' attitudes to school-life. Educational psychology textbooks invariably examine peer-influence throughout the child's development (e.g. Mussen, Conger & Kagan, 1974; Conger & Petersen, 1984; Bee, 1985; and Shaffer, 1985). While it would be inappropriate to try to precis this work here, the observer must realise that pupils are under pressure to conform to standards other than those set by the teacher, the school and the parents.

The way in which a given pupil conforms to peer-group standards is constantly assessed by others in the group and this may have a great bearing on the reactions of the individual. Different groups within the class will have different norms and those of a particular group are likely to be presented differently in lessons with different teachers.

The social structure of the classroom is also important. Teachers and pupils usually have fairly clear perceptions of how each should behave. This is not to say that a pupil's perception of his/her own role will match the teacher's perception of that role, merely that each sees a defined role for self and others. In educational innovation, there is a strong likelihood that potential changes in role will be perceived by the actors, who may feel threatened by (or enthusiastic about) these changes. Much has been written by sociologists such as Banks (1976), Bernstein (1975), Hargreaves (1972), Keddie (1973), Young (1971) and others about the social organisation of knowledge and about classroom roles and interactions. Again, it would be inappropriate to try to precis this work here, but the researcher must be aware of the existence of such constructs and of their importance in explaining classroom life and the changes which occur.

Conclusion

When observing, the activities seen should be taken as self-contained events. The process of looking for patterns is part of the analysis, not of observation. The overall process is, however, 'interactive': one moves from observation to analysis to interpretation and back again to observation. As Hamilton (1977 p.233) says,

> "Any suggestion that one first completes the study then analyses the data, and finally sets about writing a report, is misleading. The stages are not 'insulated', there is a progression."

The 'sensitising concepts' referred to above could arise from 'unstructured' observations of classroom activities and could then be used in conjunction with an existing observation schedule or shorthand. The results of these later, more structured, observations could then be used to refine the initial concepts, allowing existing observations to be re-interpreted and further observations to be better prepared. Hamilton's 'progression' (ibid) is not so much linear as helical: observations are only really complete when another 'turn' produces no 'new' information.

When observing, there can be no substitute for practice in writing descriptively, recording field notes, separating important detail from trivia and validating observations.

From the above discussions, it would seem that the most important factor necessary to produce accurate, reliable and valid observations is the quality of the observer. In observing a novel or 'anthropologically strange' situation (Atkinson, 1981), the observer is always likely to be faced with unexpected, 'chance' events and, as Pasteur said, "In the field of observation, chance favours the prepared mind."

INTERVIEWING

The basic reason for interviewing is to elucidate those things that cannot be directly observed. Interviews should be an attempt to understand the perspectives the interviewee has of the problem at hand. Feelings, thoughts and intentions cannot be observed, neither can past events nor a person's interpretation of events. The function of the interviewer is to guide the conversation so that the people interviewed can respond "comfortably, accurately and honestly" (Patton 1980 p.197) to questions of interest to the researcher and so that their (the interviewees') own 'feelings, thoughts and intentions' are revealed.

Patton (1980 p.197) suggests that there are three basic styles of interviewing to collect qualitative data, each with its own strengths and weaknesses:

> "(1) the informal conversational interview;
> (2) the general interview guide approach; and
> (3) the standardized open-ended interview."

The differences between these three styles lie in the extent to which the interview questions are determined beforehand.

Figure 2.2 is taken from Patton (1980 p.206) and it summarises the three styles of qualitative interviews and compares them with a fourth style, the closed quantitative interview.

Type	Characteristics	Strengths	Weaknesses
Informal conversational interview	Questions emerge from the immediate context and are asked in the natural course of things: there is no predetermination of question topics or wording.	Increases the salience and relevance of questions. Interviews are built on and emerge from observations: the interviews can be matched to individuals and circumstances.	Different information collected from different people with different questions. Less systematic and comprehensive if certain questions don't arise "naturally". Data organisation and analysis can be quite difficult.
Interview guide approach	Topics and issues to be covered are specified in advance, in outline form: interviewer decides sequence and wording of questions in the course of the interview.	The outline increases the comprehensiveness of the data and makes data collection somewhat systematic for each respondent. Logical gaps in data can be anticipated and closed. Interviews remain fairly conversational and situational.	Important and salient topics may be inadvertently omitted. Interviewer flexibility in sequencing and wording questions can result in substantially different respondents, thus reducing the comparability of responses.
Standardised open-ended interview	The exact wording and sequence of questions determined in advance. All interviewees are asked the same basic questions in the same order.	Respondents answer the same questions, thus increasing the comparability of the responses: data are complete for each person on the topics addressed in the interview. Reduces interviewer effects and bias when several interviewers are used. Permits decision makers to see and review the instrumentation used in the evaluation. Facilitates organisation and analysis of the data.	Little flexibility in relating the interview to particular individuals and circumstances: standardised wording of questions may constrain and limit the naturalness and relevance of questions and answers.
Closed quantitative interview	Questions and response categories are determined in advance. Responses are fixed: respondent chooses from amongst these fixed responses.	Data analysis is simple: responses can be directly compared and easily aggregated: many questions can be asked in a short time.	Respondents must fit their experiences and feelings into the researcher's categories: may be perceived as impersonal, irrelevant and mechanistic. Can distort what respondents really mean or experienced by so completely limiting their response choices.

Figure 2. 2

Variation in Evaluation Research Interview Instrumentation
(after Patton, M.Q. 1980 p.206)

(1) The Informal Conversational Interview

An 'informal conversational interview' is phenomenological in approach. Because it relies entirely on the generation of questions in situ and on a natural flow of the conversation, it has the greatest flexibility in following points of interest which arise during the interview. This style is particularly useful where the researcher has no (or few) preconceptions of what important issues may arise and where he can spend some period of time in the situation and is not reliant on a single interview. It may be especially useful in the 'illuminative' stage of an investigation. Its weaknesses, compared with the more systematic methods, lie in the greater amount of time needed to collect systematic information and in its reliance to a greater degree on the conversational skill of the interviewer and on his/her ability to establish good interpersonal relationships with the interviewees. The interviewer must be able to 'think on his feet', to react easily and quickly to changing nuances in the conversation and to guard against asking questions whose structure would impose interpretations on the situation. Variations in the questions asked between one interview and another will produce varied responses, which may tend to mask the underlying patterns of response. This lack of systematization, together with the greater length of the data, makes it more difficult to analyse. The more systematic, formal approaches are easier to analyse, but cannot respond so flexibly to individual variations.

(2) The General Interview Guide

The 'general interview guide' approach consists of a list of topics to be covered in the interview, but does not define the ordering or wording of the questions. The advantages of this method are that it ensures the same topics are covered in each interview, yet allows free conversation about those topics. It helps to make more systematic the interviewing of a number of people in a group interview situation. It focusses the interview on what the interviewer perceives to be important, yet allows the individual perceptions of the interviewees to be revealed by allowing the interviewer to respond freely to shifts in the conversation. It remains open to the researcher to decide at what depth each topic should be treated according to the responses given in the interview. Being more structured than 'the informal conversational interview', the resulting data is more easily analysed and patterns of response are more easily revealed.

(3) The Standardised Open-ended Interview

In the 'standardised open-ended interview', the exact questions to be asked are decided on beforehand. The order of the questions and any necessary elaboration or clarification are also decided before the interviews occur. This high degree of organisation makes data analysis much easier and, as the interview is sharply focussed, the available time is carefully used. Interviewer effects are also minimised and the need to make value judgements during the interview is largely removed. The weakness of this style is that individual differences and settings cannot be taken into account and the lines of questioning of different individuals are constrained. Nor, of course, can the researcher follow topics which were not thought of before the interview began.

(4) The Closed Quantitative Interview

In the 'closed quantitative interview', both questions and responses are decided in advance. The interviewee is simply asked to make a choice from a number of offered alternatives. Such a structure reduces the time taken in interviewing and provides data in a form which is readily analysed. However, it can easily distort or mask the true feelings of the interviewee and consequently requires very careful construction and testing if it is to provide meaningful results.

Any given interview need not, of course, fit completely into one or other of these categories. For example, it could be appropriate to gather certain information about the interviewee or the setting using standardised open-ended or closed questions, while the opinions or feelings of the interviewee may be gathered in a much more informal, conversational manner. The researcher should not feel constrained by simplistic or idealised methodologies.

Repertory Grid Techniques

A somewhat different style of obtaining qualitative data about people's perspectives of a topic is the use of repertory grid techniques derived from the personal construct psychology of Kelley (1955). Interview techniques are used to elicit, from the interviewee, various aspects or 'elements' which he sees as being concerned with or relevant to the topic being discussed. For example, if the topic were 'teaching chemistry in schools', then some of the elements might be: 'organising practicals'; 'the mole concept'; 'marking homework'; or any other topic which <u>the interviewee</u> saw as being relevant. Groups of the elements, usually in threes, would then be considered and the interviewee asked to say in what way any two of them were different from the third and to provide 'pole names' for the 'construct'. For example, if the construct were that 'these two are abstract and that one is concrete', then the pole names could be 'abstract' and 'concrete'. Each of the elements would then be rated on, say, a '1 to 5' scale for that construct. This would then be repeated for a different set of elements, so forming a matrix or grid. Figure 2.3 shows a flow diagram for the elicitation of such a grid (Pope 1980 (a) p.18).

Analysis of construct ratings within a grid can show how a person perceives the subject in question, what he sees as being unimportant and what factors he sees in a similar light. Factor anaysis or, more recently, cluster analysis is usually used.

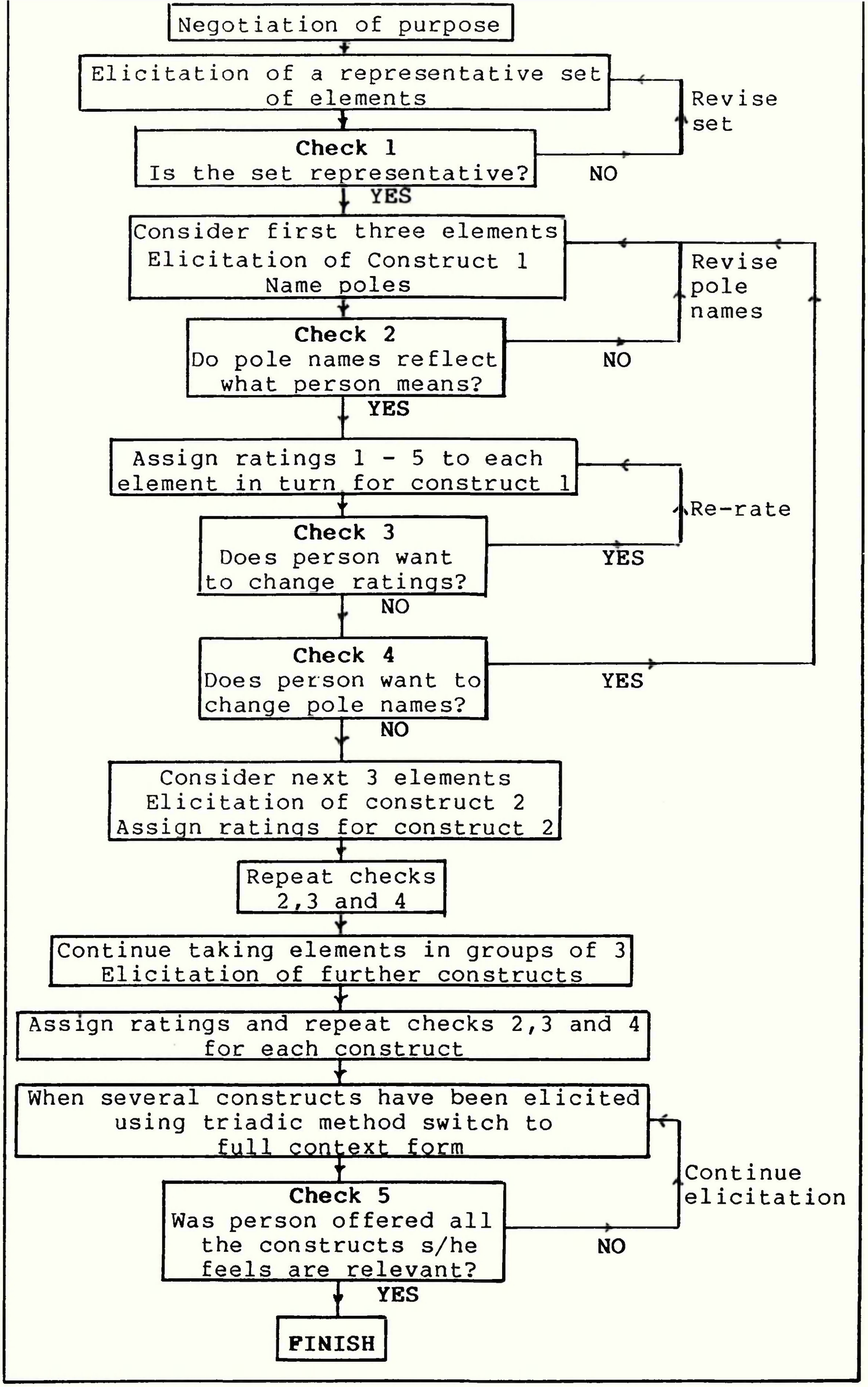


Figure 2.3

Flow Diagram for Grid Elicitation

One grid can also be compared with another so that the extent to which the interviewees share perceptions can be assessed. Despite the mathematical analyses of the finished grids, the collected data is largely qualitative in that it reflects the interviewee's view of the world and the 'numbers' are applied by the interviewee to categories constructed by him.

Question Style

In all interviewing, question style is vitally important. The questions should be clear and singular so that the interviewee understands what is being asked. Questions should also be truly open-ended and should avoid forcing people into dichotomous responses. A question such as "How good do you think the program was?" cannot be said to be 'open': it merely disguises the response categories often used in quantitative interviews (very good, good, average, poor, very poor), while asking "Did you think the program was good?" invites a "Yes" or "No" response. A more open form would be, "What do you think of the program?" This leaves it up to the interviewee to respond about the whole program or parts of it or to compare one part with another, etc. This does not mean that all questions must be carefully neutral - indeed, presupposition questions are often used. Asking, "Which was the most difficult part of the program?" presupposes that some part was difficult. While the interviewee could respond, "I didn't find any of it difficult", it is more likely that he will move directly to comparing one part with another. This by-passes the dichotomous-response form of the question: "Did you find any part of the program difficult?" and helps to focus the attention of the observer on what was difficult about the program, rather than simply asking for affirmation that something was difficult.

As with observation, note-taking is also necessary during interviews even though they are normally taped. The notes are likely to consist of key phrases and terms used by the interviewee and a list of major points covered in the interview. In the 'guided interview', it will be necessary to check-off points covered as the interview proceeds and to make a note of points of interest raised which may not be on the original guide-list. Immediately after the interview, the notes taken should be checked to see that they are clear. Similarly, the interview as a whole should be reconsidered: did the researcher really find out what he wanted to know and, if not, "What went wrong?"

Interviews can also be used as part of the process of 'negotiating entry' into an observational situation. The information gathered may not be central to the requirements of the observation and/or may be of transitory importance. Nevertheless, the relationships established in an open-ended interview may form the basis for mutual trust and support in further research work.

Once quantitative data has been collected, the analysis can be performed by standard statistical methods such as correlation, factor analysis, regression, etc. With qualitative data, however, this is not possible. Qualitative data are essentially descriptive rather than numeric and so the first step must be to analyse the **content**, to try to arrive at the commonly-held views and the patterns of interaction recorded in the data.

Generally, the analysis of the data is tackled by looking for patterns or regularities in the data and constructing a set of categories, such that various segments of the data can be assigned to a particular category. Ideally, the category set should allow each item of data to be uniquely assigned to a given category. Many different methods of content analysis can be found in the literature (Fox 1976, Guba 1978, Patton 1980, Bliss and Ogborn 1977), but all the methods have a common aim: to simplify and co-ordinate the mass of data into a much more condensed and more easily understood form.

Purpose and Levels of Analysis

Fox (1976 p.259) defines content analysis as:

> "..... a procedure for the categorization of verbal or behavioural data, for the purpose of classification, summarisation and tabulation".

The researcher can use such an analysis for three basic purposes:

i) the analysis of the 'semantic content' - what was actually said;

ii) the analysis of the 'attitudes' conveyed by the data;

iii) as a basis from which the intent or motivation of the people involved can be inferred.

Fox (1976 p.260) makes a distinction between two levels of analysis: "the manifest level and the latent level". The 'manifest level' refers to an analysis which looks only at what was done or said, without any attempt to interpret or derive meanings from the data (at this stage), whereas the 'latent level' refers to an attempt to classify the underlying motivation conveyed by the data.

Convergence and Divergence in Categorisation

In dividing the data into main categories and sub-categories, the researcher is faced with what Guba (1978) calls the problem of "convergence": that is, sorting out which items fit together. Guba suggests several stages for converting qualitative data into systematic categories. The researcher must first look for "recurring regularities" in his data which represent patterns that can be sorted into categories. The categories are then judged according to their "internal homogeneity" and "external heterogeneity" (ibid). The first criterion refers to the extent to which the data in any one category 'dovetail together in a meaningful way' - that is: do the data really fit into the same category - while the second criterion is the extent to which the differences between the categories are clear and well-defined. He says that:

> "The existence of a large number of unassignable or overlapping data items is good evidence of some basic fault in the category system." (Guba 1978 p.53)

The researcher must then move interactively between the data and the category system, checking the meaningfulness and the accuracy of the categories and the placement of the data within the categories.

When the researcher is satisfied with the category system, it should be checked for 'completeness'. Guba (1978 pp. 56-57) suggests four checks for the completeness of a set of categories:

> "1. The set should have internal and external plausibility ..... Viewed internally the categories should appear consistent; viewed externally the set of categories should seem to comprise a whole picture .....
>
> 2. The set should be reasonably inclusive of the data and information that do exist .....
>
> 3. The set should be reproducible by another competent judge ..... The second observer ought to be able, however, to verify that (a) the categories make sense in view of the data which are available, and (b) the data have been appropriately arranged into the category system...
>
> 4. The set should be credible to the persons who provide the information which the set is presumed to assimilate ..... "

The second problem which Guba discusses is that of "divergence" or what he calls "fleshing out" the set of categories by:

- collecting data which will describe the points of interest in some detail;
- providing perspectives for viewing them;
- developing enough evidence to enable judgements to be made about these points.

He suggests (Guba 1978 p.59) that this is done by

- "extension" - building on information already known;
- "bridging" - making corrections or finding relationships between different items;
- "surfacing" - suggesting new information that ought to exist and then verifying its existence.

When attempting to use the available information to "flesh out" the categories, the researcher must make decisions about which information should be included and which should be excluded. Guba (1978 pp. 59-60) suggests seven criteria for determining inclusion or exclusion of information. Information should be included if it:

- "extends the area of information", provided it is relevant to the area of research;
- "relates or bridges several already existing items";
- "identifies ['surfaces'] new elements of importance".

New information should be added if it:

- "tends to explain other information already available";
- "exemplifies either the nature of the category or important evidence within the category";
- "tends to refute existing information".

Information should also be added if it

- "reinforces existing information" unless it "begins to approach mere redundancy".

Such criteria imply that information can be excluded where it is redundant, irrelevant or immaterial.

Cross Classification

Once some categories or dimensions have been constructed, it may be useful to cross-classify some categories to provide new insights into interaction patterns or the organisation of the data, which may not have been apparent during the initial content analysis. Figure 2.4 (overleaf) is taken from Patton (1980 p.315) and shows the resultant matrix formed by crossing the categories of "Teacher's Beliefs ....." (three sub-categories) with "Teacher's Behaviour ....." (two sub-categories).

Patton (1980 p.316) says that the six category cells of the matrix greatly facilitated the analysis and interpretation of the data: "the whole thing immediately fell into place" and working back and forth between the matrix and the data enabled a "full descriptive analysis" to be generated.

The process is brought to closure when sources of information are exhausted; or tend only to give redundant information; or suffer seriously from the effects of 'diminishing returns'. Closure may also be indicated when new data is seen to fit into already well-established patterns. However, this alone should not be seen as sufficient for closure, as some areas of important information may not have emerged - simply those that have are showing a regular pattern. Finally, closure may be indicated if the information one is collecting is felt to be too far removed from the issues which formed the subject of the research.

Behaviours Toward Dropouts

Taking Responsibility——Shifting Responsibility

Teacher's Beliefs About How to Intervene with Dropouts

	Taking Responsibility	Shifting Responsibility
Rehabilitation	Counselor/Friend: Helps kids directly	Referral Agent: Refer them to other helping agencies
Maintenance (Caretaking)	Traffic Cop: Just keep them moving through the system	Ostrich: Ignore the situation and hope someone else does something
Punishment	Old Fashioned School Master: Make them feel the consequences	Complainer: Somebody should remove the problem kids

Figure 2.4

An Empirical Typology of Teacher Roles in Dealing with High School Dropouts

Validity, Reliability and Objectivity

Questions of validity, reliability and objectivity apply to qualitative data as much as they do to quantitative data. However, it is rare for mathematical treatments of these factors to be applied to qualitative research and Guba (1978 p.62) has suggested new terms for use in qualitative research, to avoid confusion with the more conventional connotations of these terms. He uses 'intrinsic' and 'extrinsic adequacy' in place of 'internal' and 'external validity', 'replicabililty' instead of 'reliability' and 'impartiality' or 'neutrality' instead of 'objectivity'.

Guba (ibid) reports an analysis by Speizman (not dated) of invalidating factors which may be present in qualitative research:

"(1) distortions resulting from the researcher's presence at the research site;

(2) distortions resulting from the field-worker's involvement with his subjects;

(3) distortions resulting from bias on the part of the field-worker or his subjects;

(4) distortions resulting from the manner in which data-gathering techniques are employed."

Speizman suggests that all these can be overcome by the researcher constantly checking and rechecking his own work, preconceptions, hypotheses, etc. and by providing opportunities for these "to be thoroughly challenged by the data he collects."

Intrinsic Adequacy

Perhaps the most important method of ensuring intrinsic adequacy is 'triangulation', that is the use of a multiplicity of research techniques to assess a single situation, event or hypothesis. Denzin (1971 p.177) says,

> "Triangulation forces the observer to combine multiple data sources, research methods and theoretical schemes in the inspection and analysis of behavioural specimens."

Adelman (Adelman, 1981 (b) pp78-97) and Cicourel (Cicourel and Jennings, 1974) use triangulation in the somewhat different sense of discussing the observer's reports with the people observed (teachers and pupils in this study). This gives perspectives arising from "different physical, temporal and biographical" sources (Cicourel, ibid) which can all be used in ensuring as complete a picture as possible is built up.

Similarly, House (1977) observes that,

> "Validity is provided by cross-checking different data sources and by testing perceptions against those of participants."

Webb et al (1966 p.3), while accepting the inherent difficulties, also strongly support triangulation,

> "Once a proposition has been confirmed by two or more measurement processes, the uncertainty of its interpretation is greatly reduced."

Finally, Patton (1980 p.109) says that,

> "Triangulation is ideal. It is also very expensive."

The "expense" comes, of course, in the extra time needed to use multiple methods and sources.

In addition to the use of multiple perspectives, as above, it is also possible to improve intrinsic adequacy by multiple observations from a single perspective. Eisner (1975 p.18) makes the point that,

> "Classrooms or schools are not so fugitive that their pervasive qualities change on a daily basis. What is enduring in a classroom is more likely to be educationally significant than what is evanescent."

Extrinsic Adequacy

The first point Guba (1978 p.67) makes, in considering extrinsic adequacy or generalizability, is that "for many evaluation purposes [it] is meaningless". He argues that the majority of educational evaluation is aimed at a particular event in a particular setting and generalizability is irrelevant but that, in many situations, generalizability may be seen as important and, in discussing this situation, Guba (1978 pp.68-69) suggests several possible alternative views of generalizability:

> "it is impossible to generalize in the scientific sense at all";
>
> "generalizability continues to be important";
>
> "generalizability is a fragile concept whose meaning is ambiguous and whose power is variable."

While few people would accept the first view as a serious scientific standpoint, the second and third views are both important. Denzin (1971) suggests several ways in which qualitative research can be made "generalizable" and these are summarised in Figure 2.5 below.

Focus of Investigation	Extent of Generalizability
A representative situation	All persons who 'pass through' that situation
A time (i.e. a particular season, month, holiday)	All persons in that timeframe
Special Populations	That class of social organisation (e.g. schoolchildren, doctors, patients)
A recurring encounter	That type of encounter or the population of which the persons involved in the encounter is a sample

Figure 2.5

Generalizability of Qualitative Research

(after Denzin, N.K. 1971)

Cronbach appears to strongly advocate the third view of generalizabililty and offers several examples (1975 pp. 122-123) of how generalizations, made even under the "best quantitative research conditions", decay with time. (e.g. "the failure of D.D.T. to control mosquitoes, as genetic transformations made them resistant to the pesticide.")

Guba (1978 p.70) suggests that these conflicting views can to some extent be resolved. He suggests that the researcher should

> "ensure that the intrinsic adequacy is good; use 'the Denzin tactics for building credibility' wherever possible and treat 'each possible generalization only as a working hypothesis, to be tested again in the next encounter,' rather than as a conclusion."

Replicability

Many of the arguments about the usefulness of extrinsic adequacy (generalizability) also apply to replicability and the dominant view is that replicability should be built into the research design wherever possible. One form of replicability was mentioned earlier: the need for sets of categories to be replicable, i.e. a second "judge" should be able to understand how the categories were derived from the data and how the data was assigned to the categories. It is also important to build replicability into the research design by, for example, dividing the observation situations and interview candidates into two random halves and comparing the data generated by each half.

Neutrality

The neutrality or objectivity of the data is of great concern in any enquiry; the data should be factual, reliable and confirmable. Guba (1978 pp.74-75) says that there is "no intrinsic reason" why data generated by qualitative research should be any less 'objective' than that gained in quantitative research. He uses, as a example, the racial bias said to exist in many "objective" tests and says that the real issue is not the "<u>intrinsic</u>" objectivity of the data, but rather the "<u>confirmability</u>" of the information after it has been obtained. The methods of establishing intrinsic adequacy (triangulation, repeated observation) could also be used to ensure neutrality. Such tests may not, however, expose the conscious or unconscious biases and prejudices which the researcher, or the subjects, may bring into the research situation. While the researcher may hope to eliminate the effects of bias in the subjects, he may not be able to avoid the influence of his own biases. Furthermore, if the subject's bias coincides with the researcher's bias, then this may be accepted as genuine data, whereas a conflict of biases may lead to a rejection of the data, and it may be that only checking by an independent third party would reveal the effects of such biases. Similarly, the researcher may mistakenly assume that the background experience, psychological characteristics and conceptual analogies of the subject are like his own and therefore make erroneous deductions about the meaning or interest of what the subject said. The researcher should try to be constantly aware of these effects, whether observing, interviewing, or analysing the data and should not "assume that he understands all the subtle distinctions that exist in the mind of the informant." (Guba 1978 p.77)

Conclusion

In conclusion, when planning an educational research project, one is faced with two distinct paradigms: one of which implies the use of quantitative methodologies and one of which implies the use of qualitative methodologies. Traditional scientific research has sought to establish causal relationships between events, by formulating hypotheses and making measurements under carefully controlled conditions, so that laws or theories could be deduced. This hypothetico-deductive view of the scientific method has proved very successful in the natural sciences, where variables can be isolated and conditions rigorously controlled. In the social sciences too, this paradigm was assumed to be **the** scientific method and psychologists, educationalists and others have attempted to demonstrate causal relationships in carefully controlled experimental or quasi-experimental conditions (Campbell and Stanley 1966).

In any educational situation, the number of parameters is extremely large and the interactions between the parameters are subtle and complex. Furthermore, the existence of these interactions need not imply a causal relationship between the parameters and so, the application of the hypothetico-deductive paradigm to a situation may be not only difficult in practice, but also wrong in theory. Parlett and Hamilton (1977 pp.8-9) have criticised, in some detail, the applicability of this paradigm to educational research saying,

> "..... its artificiality would render the exercise irrelevant, rarely can 'tidy' results be generalised to an 'untidy' reality."

Even in the natural sciences, it has long been recognised that the actual act of measurement changes that which is measured (Heisenberg's uncertainty principle) and it should be recognised that if, in order to assess the effect of a particular educational practice, one has to impose a number of constraints, then the effect of the practice **in its natural setting** may be changed drastically by these constraints.

Patton (1980 p.20) says that the need to choose one of the paradigms is now being replaced by "a new paradigm - <u>the paradigm of choices</u>". Others refer, perhaps more simply, to an eclectic approach, which recognises that different situations require different techniques and it is this approach which would, perhaps , prove most satisfactory in the field. Like the desire to delineate a unified field theory in theoretical physics, perhaps it would be desirable to have a 'unified evaluation theory'. However, one is faced with a duality of theories and must use the one which is best fitted to the given situation.

In such a novel and rapidly changing field as computer assisted learning, the development of CAL material and the evaluation of its effects in the classroom should be seen as two, closely-interwoven parts of a single process which cannot be separated without damage to both aspects. Because the field is so new, there is no body of "received knowledge" on which the designers can draw in designing a CAL unit: they must rely on feedback from evaluation studies to enable modifications to be made to the unit to optimise its effectiveness. This is only possible where the development and evaluation aspects run concurrently. In addition, the evaluator must be closely involved in the development of units if he is to understand the intentions of the designer and the constraints placed upon him.

In developing a CAL-unit, the designers must keep clearly in mind the way(s) in which the unit is likely to be used in the classroom and must select an appropriate type and style of programming for each section of the unit. Shaw (1981,1982) has suggested six categories for types of programs in common use.

Simulation - This can include industrial processes; experiments which, for a variety of reasons, cannot usually be performed in the school laboratory; and experiments which can be carried out in schools, but which provide situations where the speed of operation of the computer can allow a much more detailed investigation - What happens if .... ? - than would otherwise be possible.

Modelling: This type of program allows theoretical models to be explored, in a way which avoids the need for the pupils to do those mathematical calculations which would obscure the essential teaching-point.

Games: Well-constructed games can provide high-level motivation for learning and can help to develop problem-solving skills. Burkhardt states, "The swift interactive response of the micro and its flexibility within a well defined set of rules make it particularly effective in setting up game situations."
(Burkhardt, Fraser and Wells 1982)

Remedial/Reinforcement Exercises:

The use of a computer with individuals or small groups can provide a secure and well-motivated environment, in which the pupil can practise and develop skills without his lack of knowledge being displayed to the whole class.

Electronic Blackboard:

In this format, the computer can act as a teaching aid, in which the display - graphs, diagrams etc. - can be responsive to the demands of the pupils. The interactive nature of the program can make this a powerful aid in class-teaching.

Programmed Learning:

The computer can present a programme which is much more highly branched than would be practicable in a "pencil and paper" environment and can keep records of the pupils' progress. This type of use, however, is much less common in this country than in the U.S.A.

Burkhardt (ibid.) has also suggested six categories of program style (neutral, expository, investigatory, competitive, cornucopian and diagnostic) which can be seen, at least in part, as forming a second dimension to be considered in the design of programs. For example, competitive elements are not restricted to "academic gaming" situations, but can also play an important part in the simulation of an industrial process, with each individual or group of students trying to achieve the "best" result. Similarly, diagnostic elements of program design need not be restricted to programmed learning or remedial/reinforcement situations, where an individual student is working with a CAL unit. Indeed, it would be valuable in matching the feedback given to the user's needs in most programs. Burkhardt (ibid.) says, "We have observed in the classroom that many programs help the teacher to understand the pupils' level of comprehension by the pupil response that they provoke".

Burkhardt (ibid) has also suggested a further dimension in the classification of programs: "program personality". In this, he includes "humour", "warmth", "praise and criticism", "stress" and "patience and impatience". The extent to which these various facets of the "program personality" should be evident in a program, poses a problem for the designer which clearly illustrates the need for feedback from evaluation studies. "Warmth" in a program is clearly desirable in the sense that the users should see the demands made by the program as "worthwhile, achievable and, preferably, enjoyable" (Burkhardt et al., ibid). However, the use of "humour" or "stress" in a program would need to be evaluated very carefully as any misuse of them is likely to produce a negative response in the users.

Ideas for new units can arise in a variety of ways: there is no single "good" way of generating ideas for teaching units. There are, however, several well-known methods by which ideas can be generated (Burkhardt, Clowes, Eggleston and Fraser, 1982). One of the most widely used methods is "brain-storming", i.e. a group discussion specifically aimed at producing a wide range of ideas, in which all criticism is withheld in the initial stages. Such sessions can be very productive and are widely used, by groups involved in software production and as a means of generating ideas on in-service courses etc. Suggestions for new units can also arise from a careful examination of the ideas and material used in related areas of CAL-work and in other media and, finally, the practising teacher may perceive the need for a unit to aid his work with a particular topic or aspect of his teaching.

In discussing the suitability of the ideas generated for development into CAL units, Burkhardt (ibid.) has suggested nine points, some or (ideally) all of which should be applicable to the unit in question. These are:

"1. can be used by a wide range of teachers whose style of teaching varies a great deal;
2. can be of use to a wide-age range of pupils;
3. can be of use to a wide ability-range of pupils;
4. can encourage work on concepts as well as on content;
5. may be of use in more than one subject discipline;
6. is suitable for demonstration mode with a large class;
7. is suitable for small groups or individuals to use;
8. can be used to produce further teaching materials;
9. can be used in teacher training."

It should be noted that the nine points are not concerned with program structure, transferability to other machines, 'bugs' in the program or how the program is driven. Such items are extremely important for the program designers, but much less so for the class teacher. Problems related to program design <u>should</u> have been settled before the program is published. However, the effects of design decisions on the teaching and learning process are largely unknown. A program specification will include a detailed description of what the program is expected to do in the classroom, how it is to be "driven" by the users and how the program is to present information to the user - in terms of screen design, the use of a printer etc. However, the educational significance of such things as the screen design and the method by which the user controls the program is still a matter for conjecture, providing yet another instance of the need for evaluative studies to run alongside the development process.

The B.P. Fellowship which funded this study was concerned with the development of CAL-material as well as the evaluation of its effects in the classroom. During the study, the author worked closely with a number of teachers and others involved in the development of CAL-material in Chemistry, Physics, Biology, History and Economics. Series of regular meetings ensured that there was close contact between the evaluation and development sides - many individuals were, of course, involved in both. The exchange of observations and ideas at these meetings resulted in changes, sometimes drastic, being made in the design of programs and in new light being shed on observations. The two processes, development and evaluation, are not separate - each affects the other. At the start of this study, little software was available: by comparison there is now a plethora. Much, though not all, of the software observed in use was still in the development stage. That it was available, greatly increased the teachers' range of choice when planning lessons. Had the evaluation had to wait for a finished product, then a valuable chance to influence - beneficially - the development of new curricular materials would have been lost.

Chapter Three

The Design of the Study

INTRODUCTION

The initial aim of this B.P. Schoolteacher Fellowship project was to develop computer assisted learning materials for school chemistry and to evaluate the use of such materials in teaching chemistry. As has been discussed in Chapter 2, the evaluation was seen as contiguous to the development and each was seen as being of benefit to the other. Furthermore, at the start of this project, there was little or no commercially available CAL material written specifically for use with microcomputers, making it even more important to improve the existing material and/or to develop new material for use in the classroom. However, the part of the fellowship reported in this study is concerned with the evaluation exercise, the principle aim of which is to establish the qualitative effects which the use of CAL material has on the teaching and learning activities within the classroom.

An investigation of the effects of CAL in the classroom can be seen as exploring a completely new field in which almost all the fundamental aspects have yet to be discovered. At the time of starting this study, there had been only one major, U.K. research programme into the effects of CAL in the school classroom (Investigations of Teaching with Microcomputers as an Aid, ITMA) and this was concerned with CAL in mathematics teaching. Hence, experience of research in this area was very limited and few guidelines had been established. It was necessary, therefore, to search for appropriate methods of evaluating the effects of the use of CAL-units in the classroom.

Because the exposure to CAL currently forms only a small part of the total learning experience, the pupils' gain in knowledge, understanding and motivation consequent upon the use of the computer could not be assessed by the more traditional pre-test, post-test methodology. Moreover, a search of the literature threw serious doubt on the wisdom of such an approach and clearly demonstrated the need to follow a qualitative approach to the evaluation.

An early series of 'unstructured observations' revealed possible areas of interest and showed the need for a more systematic method of recording the observations. After much reading, and discussion with colleagues, it was decided to use the Systematic Classroom Analysis Notation, SCAN (Beeby, Burkhardt and Fraser, 1979) to observe a range of lessons taught by several teachers. It was intended that the analysis of the SCAN records would be used both to establish the effects of CAL in the classroom, by looking for valuable learning experiences; and to delineate "good practice" in the use of the computer in such roles as "task-setter" and "tactical manager" in a range of problem-solving situations. (Fraser et al. 1985)

In addition to establishing the qualitative effects of CAL, SCAN could also provide some quantitative measures related to the various interactions which occurred within the lessons, such as the frequencies of different types of questions asked by teachers and the use of explanations, assertions and instructions etc.

Some simple questions such as:

How many micro's are there in school?

What type of micro's are used in school?

How often are they used?

What software is used?

What are teachers' attitudes towards CAL?

seemed likely to be susceptible to rather more controlled investigation - but these were not seen as the most interesting from a fundamental point of view. Such questions as these, together with questions of LEA and school/department policy, were, however, of interest to the developers of CAL. It was, therefore, decided to use questionnaire techniques to provide a basis of fact to replace the many suppositions regarding policy and provision. As stated in Chapter 1, the analysis of the questionnaires will be reported in Appendix 1.

The most important aspect of the evaluation was seen to be an examination of those changes in teaching and learning strategies (and the corresponding teacher and pupil role-changes) made possible by the use of CAL, which would result in a qualitatively improved learning environment. The delineation of these changes would, of course, rely upon the direct observation of classroom activity. For example, in many preliminary observations, the computer was seen to take on the role of task-setter, a role which would otherwise have taken up a large proportion of the teacher's class-contact time, thus giving the teacher the freedom to discuss with the pupils possible problem-solving strategies and the principles underlying the topic.

RECORDING THE OBSERVATIONS

In investigating any new situation, one is inevitably faced with the problem of choosing a suitable research instrument. Because the use of CAL in schools is so new, there have been no clear indications established of the CAL-related phenomena one might expect to observe in the classroom. It was decided, therefore, that the initial investigations should be purely "illuminative", with the aim of indicating both the broad areas of change likely to occur and the type of research instrument needed to record them. Consequently, the first set of observations were completely unstructured and their analysis relied upon the use of hand-written "field notes" and cassette sound recordings. These initial observations illustrated the need for, what can best be described as, an 'interaction shorthand', which would allow the systematization of the recordings without imposing irrevocable on-the-spot decisions about the nature of the intellectual transactions.

It was finally decided to use a system developed at the University of Nottingham, by Hugh Burkhardt and others, which was originally intended for recording observations of mathematics lessons: The Systematic Classroom Analysis Notation, SCAN (Beeby, Burkhardt and Fraser, 1979). This provides "a means of recording what is observable in a lesson, i.e. the teaching and the pupil response to that teaching" (op. cit.). SCAN is intended to produce a description of a lesson in a manner which allows a detailed analysis to be made at a later stage; it provides a means of recording phenomena in 'real time' and, unlike many observation schedules, does not divide the lesson into arbitrary time-slices. Beeby et al. (op. cit.) say:

> "SCAN allows an observer to record live the essence of the dialogue.......and to relate it to content, teacher objectives, pupil work and the use of resources. It works simultaneously on three time scales - the Event, the Episode and the Activity."

Learning, unlike teaching, is an internal process and, therefore, not directly observable but, because SCAN allows the pupils' responses to be analysed, it was felt that some inferences could be made about the intellectual level at which the pupils were working and about their success in internalising the subject matter of the lesson.

The Structure of SCAN

When recording a lesson, SCAN operates on three levels or time scales: the activity, the episode and the event. The observer uses a coding system of linguistic descriptors to record the details of the remarks or events which occur. A group of these remarks or events are seen as forming an episode within the lesson and the episodes, in turn, link together to form the series of activities which comprise the lesson.

"Activities" form the principle subdivisions of a lesson and include, for example, pupils working in groups of "n" (Wn), teacher talking to a small group of pupils (D) or teacher exposition to the whole class (Ew) - Table 3.1. Such activities are fairly self-evident and changes of activity are readily recognised and recorded by the observer.

E - Exposition teacher to whole class (Ew) or to group of 5 or more (En)	PP - Pupil-pupil dialogue (use "t" to prefix teacher remark)
D - Dialogue teacher to group <5	Wn - Pupil Work in groups of n
T - Teacher initiated	P - Pupil initiated

Table 3.1

Activity Level

Each activity can be seen as consisting of a number of "episodes" such as explaining new material (E), coaching individuals or small groups of pupils (CO), or revising earlier work (R) - see Table 3.2. Again, the point of change from one episode to another is usually clear - the teacher may move to the next group of pupils or initiate new work.

It is, however, at the "event" level that SCAN records the greatest detail of the elements which go to make up the lesson. Each event recorded may require up to four descriptors: the initiator, the linguistic role of the event, the depth of demand made of the pupil and the level of guidance given.

D - Defining	CO - Coaching
I - Initiating Activity	E - Explaining new material
C - Confirming	R - Revising
SS - Searching Successfully	SU - Searching Unsuccesfully
CN - Conversing	F - Facilitating
AR - Arguing (Resolved)	AU - Arguing (Unresolved)
CP - Competing	

Table 3.2

Episode Level

Social, Organisational, Procedural	
g - gambit	m - managerial
ch - question for checking	w - withdraws statement
p - observation	v - vote
l - leaves discussion	
Associated with Content	
q - question of	a - assertion
e - explanation	s - suggestion
cc - conclusion	b - boing
x - giving example	i - instruction/ initiation
cf - confirmation	r - rejection
k - correction	

Table 3.3

Event Level

Linguistic descriptors such as questions of content (q), explanations (e) or corrections (k) etc. are easily recorded as in Table 3.3 above.

As the main interest is in the intellectual transactions in the lesson, other events are simply divided into managerial events (m) and gambits (g), which include all "facilitations" and "social and sociable" comments. It should be noted that the record should show the role of the event as perceived by the pupil - for example: an interrogative statement would be recorded as a question, while a rhetorical question might be treated as an assertion or an explanation.

The initiator is assumed to be the teacher unless otherwise labelled - the prefix "p" indicates an unspecified pupil as the initiator, while a number 1,2,3...... can identify a particular pupil if the dialogue is recorded or a sketched seating plan is made.

If a detailed account is to be made of the events in a lesson, then some qualification of the linguistic descriptors is necessary. Answering a question, for example, could involve a pupil in simple recall of a single fact, in the synthesis of observations to form a "new" hypothesis or anywhere in between. Similarly, the way in which a question is phrased can vary between a highly-structured, closed-ended form and an open-ended, investigatory style. SCAN provides a set of qualifiers both for the "depth of demand" and for the "level of guidance" implicit in a remark or event - these are shown in Table 3.4.

The depth of demand is described on a three-point scale:

α - the recall of a single fact or act.

β - the connection of several facts or acts. For example, a pupil may be asked to list the physical properties of covalent compounds or to describe what was seen in an experiment.

γ - an extension of previous skill or understanding. This may involve fitting experimental data to an existing pattern or generating a 'new' pattern from the data.

The level of guidance is also described on a three-point scale:

1 - maximum guidance: a highly-structured situation in which the pupil recognises that a choice must be made from a restricted number of alternatives.

2 - a more open situation in which connection, rather than simple selection, is required; the basic nature of the demand, however, is still made clear to the pupil.

3 - minimum guidance: an open-ended situation in which the pupil must choose from a wide range of alternatives, synthesise data and ideas, generate "new" hypotheses etc. The situation is left as open as possible.

Depth of Demand	Level of Guidance
α - recall of single fact or act, no processing involved	1 - highly structured, close guidance, small number of alternatives
β - connection of several facts or acts	2 - less guidance given, requires connection of facts rather than selection
γ - extension of previous work involving new ideas	3 - minimum guidance, open-ended
Prefix "p" for pupil-initiated event	

Table 3.4

Qualifiers

The way in which the "demand" and "guidance" qualifiers are applied depends upon the context of the event, including the previous experience of the pupils. For a fifth-year chemistry pupil, the "depth of demand" of a question such as "Why do these solutions turn litmus red?" would almost certainly be classed as "α" while the same question to a first-year pupil might be seen as "β" or even "γ".

The response to questions is also recorded - see Table 3.5 - and the various other codes used are shown in Table 3.6.

✓ - correct	$\frac{t}{o}$ - teacher does not take response
v - partly correct	
x - wrong	hc - hypothesis confirmed
o - no pupil response	hr - hypothesis rejected
$\overset{\checkmark}{h}$ - consistent hypothesis	
$\overset{\times}{h}$ - inconsistent hypothesis	

Table 3.5

Fate of Questions

RESOURCES	MISCELLANEOUS
TM - teacher material	$\overset{t}{x}$ - teacher slip
PMB - printed material (books)	$\overset{c}{x}$ - computer slip
PMC - printed material (cards)	z - major tactical change
C - computer	R - resource in use
BB - blackboard	$\cancel{R}$ - use ended
OHP - overhead projector	... - time to think

Table 3.6

Other Codes

Finally, the elapsed time is noted - usually at each episode boundary - to provide a record of the time spent on different aspects of the lesson.

The Use of SCAN in the Classroom

To produce a SCAN record of a lesson, the observer need have nothing more than a piece of paper and a pencil, although a cassette recorder is useful in that a sound recording of the lesson allows the exact phrasing of a question to be noted and provides a means by which one's initial impressions of the "demand" and "guidance" given can be checked. The simplicity of operation allows the observer to make minimal impact on the classroom environment and experience has shown that the pupils, at least, rapidly become accustomed to the presence of an extra person in the room. Nevertheless, it is important that the observer should negotiate carefully his entry into the classroom and that he should make clear the reasons for the observations: he must avoid giving the impression that either the teacher or the class are being 'tested'. All the teachers observed in this project were visited at least once - and usually several times - before the initial observation to ensure that, as far as possible, the teacher did not feel 'threatened' by the observer's presence.

Before each lesson, some time was spent talking to the teacher about the background to the lesson - what work the class had done previously on the topic, how the topic fitted into the curriculum, the relative ability of the class, etc. Some time was also spent at the end of each lesson talking to the teacher, to assess his/her perceptions of the lesson: whether the lesson went more or less as intended, the usefulness of the CAL unit, and the effect of the unit on the teaching and on the pupils' response to the teaching. In practice, the time available was found to be very limited, as the teachers were normally coming from, or moving to, other lessons or duties.

Finally, the observer's initial reactions to the lesson were recorded as soon as practicable after the end of the lesson - either in note-form or on cassette - as it was felt that this could prove a useful adjunct to the SCAN record in interpreting the observations.

Adequacy and Replicability of SCAN

Whenever data is gathered by direct observation of classroom behaviour, it is important to consider the extent to which other observers would produce similar records when observing the same lesson. Beeby et al. (Beeby, Burkhardt and Fraser, 1979) report some studies of the replicability of SCAN records, in which good agreement was found in the records produced by nine different observers viewing an extract from a video-taped lesson.

The author was trained in the use of SCAN at the University of Nottingham's Centre for Mathematics Education, using a number of video-tapes of mathematics lessons. After some practice, a 'first-time' SCAN was produced from a video of another mathematics lesson (i.e. a SCAN written on the first viewing of the recording, without slowing, stopping or replaying the tape). This was then compared with SCANs produced by the originators of the system. While there was, of course, a number of minor differences, it was felt that these were not significant and would not lead to differences in the interpretation of the phenomena observed.

Replicability must also be concerned with consistency of use in the field. The way in which an observer uses SCAN and interprets the observations should not show erratic variations in quality from one occasion to another. Some variation, however, is inevitable and it was felt that this could only be overcome by repeated observations: random changes due to the observer would then be less important over the series as a whole. As the research was concerned with differences, small biases in the way in which events were recorded would 'cancel out', provided they were consistent throughout.

It was felt to be desirable for the observer to have some way of checking the adequacy of SCANs taken in the field. To allow, to some degree, the 'triangulation' techniques referred to in Chapter 2 to be used, it was decided to make sound recordings, using a cassette-recorder, of all the lessons observed. This would allow the adequacy to be checked in two ways: a SCAN could be made from the recording and checked against the 'original' SCAN; and the observer's interpretations of the dialogue could be checked against his interpretation of the SCAN. It was also felt that the ability to ascribe specific classroom dialogue to specific events recorded in the SCAN could be useful, not only in checking the intrinsic adequacy, but also in aiding the further interpretation of the observations.

An examination of the early recordings revealed that the quality was too poor to allow full SCANs to be made from them. The level of background noise, the poor acoustics and the fact that, often, many people were speaking at once made it difficult to SCAN or transcribe accurately. However, some passages within the tapes were found to be clear enough to allow SCANs to be checked and to allow a limited transcription. The ease with which such passages could be identified within the original SCAN and the good match between the identified sections and the SCANs made from the recordings, provided further evidence for the replicability of the observation process.

Evidence from these early recordings and SCANs indicated qualitative changes in pupil and teacher 'talk' associated with changes in the nature of the task set when CAL was used. It was felt to be important to have some good quality recordings of the teacher-pupil and pupil-pupil dialogues concerned, so that the actual use of language within an 'event' could be considered. After discussion with colleagues, it was decided that it would be most appropriate to record a number of lessons in the T.V. studio, as this would provide the best sound quality and allow easy identification of speakers. These tapes would allow some triangulation of techniques to check the adequacy of the observation process and could also be used as a further check on the replicability of the SCAN process.

It was felt that it would be most useful if the studio sessions involved teachers and classes chosen from those participating in the final phase of the observations. In choosing the individual lessons, it was felt that they should involve the use of CAL and should form part of the 'natural' progression of the lessons in the school. In this way, only the minimum changes would be made: the pupils would be accustomed to being observed, they would have some familiarity with the computer and they would have the background knowledge gained from the earlier parts of their courses.

Before each recording, the teacher and pupils involved were encouraged to examine the equipment in the studio and to 'have a go' with the cameras. It was hoped that this would help to reduce their interest in and curiosity about their surroundings during the actual 'lesson'. This seemed to work in practice: observation of the recording process supported the view taken by Barnes and Todd (1981, p71) that, although the pupils could not be unaware of the recording, there were many times when they "seem[ed] to have forgotten". The lessons recorded will be discussed in detail in Chapter 4: they were DALCO, FORMULA, ANIMAL, LENS, FERTILIZER and ELEMENT. For simplicity, <u>all</u> the programs used in this study will be referred to by a NAME in upper-case type. Details of these programs and their sources, is given in Appendix 2.

It was felt that the extrinsic adequacy of the interpretations (the extent to which they are generalizable) could best be checked by repeated observations and by cross-checking the observer's interpretation of events with the teachers involved and with others involved in the development and evaluation of CAL-material for schools. There is no simple formula for ensuring extrinsic adequacy: to some extent, each classroom is unique and it was only after seeing similar events occurring in many situations that the observer could begin to generalize. It was also felt that cross-checking the findings with others interested in the field would be helpful in highlighting any observer bias and so help to ensure the neutrality of the interpretation of the observations.

Interpreting SCAN Records

In order to illustrate the way in which the SCAN record can be related to the phenomena occurring in a lesson, the opening episodes of a fairly typical lesson will be considered in detail. Table 3.7 shows an extract of the "SCAN" from the start of a lesson. Even without a transcription of the dialogue, the SCAN record can easily be read back. The SCAN shows that the lesson opened with a revision episode in which the teacher talked to the class as a whole. The teacher used managerial (m) and social statements (g) to gain the attention of the class. He then made a simple assertion (aα1) about the homework to be revised and moved on to a checking question (ch). A pupil responded satisfactorily with a simple assertion (paα1) and the teacher confirmed the response (cf). The teacher then made a series of observations (p) and assertions (aα1), using the blackboard to emphasise or list the points covered. The episode finished with an observation by a pupil (pp) and a further observation (p) by the teacher. This initial episode lasted for five minutes. A second, shorter revision episode of three minutes followed, in which the teacher, after some initial managerial and social comments, again used the blackboard to list the points made by a series of assertions regarding the work covered in the previous lesson.

Resources Used	Activity time	Notes/ % on task Events/Episode Summaries// Resources/options used
BB	Ew 1.21	homework m/g/g/aα1/ch/paα1/cf/p/p/aα1/aα1/ R $\cancel{R}$
		ch/paα1/pp/p//R
	1.26	m/g/m/aα1/aα1/aα1//R R $\cancel{R}$
	1.29	(etc.)

Table 3.7

SCAN of the Opening of a Lesson

Table 3.8 gives a transcript of the opening episode of the lesson so that the actual dialogue can be compared with the SCAN notation.

Teacher	Right! Can you open your books at that homework first of all.	m
T.	Are you ready?	g
T.	I just want to go over the answers to these questions before we start today's experiment.	g
T.	Part 1 asks, "Is the electrolyte solid, liquid or in solution?"	aα1
T.	What's the answer? Andrew?	ch
Pupil	Liquid.	paα1
T.	It's molten, yes, or liquid.	cf

Table 3.8

Opening Dialogue Related to SCAN

It should be remembered that, in any observer-recording system, it is the perceptions of the observer which are recorded; perceptions which are themselves situation-dependent. Thus "Are you ready?" could variously be a gambit (as recorded here), a checking question or, given very different circumstances, an assertion or instruction. Even the existence of the question mark is dependent on the observer's perceptions of what was said.

In practice, it has been found that different, independent observers produce very similar SCANs when observing the same lesson. Such differences as do arise are minor and do not affect the interpretation of the SCANs in any materially important sense. For example, whether one regards "Are you ready?" as a gambit, indicating the teacher's intention to start the discussion or simply as the teacher checking to see if everyone has found the appropriate place in the book, makes little difference to the overall interpretation of the SCAN.

SELECTION PROCEDURES

Ideally, any group of teachers taking part in an educational experiment should be representative of the teaching population as a whole. In attempting to evaluate the effects of CAL, however, one was forced to choose from a group of teachers who, because the use of CAL in schools was so new, could be regarded as 'innovative' and, therefore, as deviating from the norm. However, the number of teachers using CAL was increasing rapidly and it was felt that it would be possible to select teachers representative of a wide range of teaching styles.

Formal permission to undertake research in schools was sought from the Directors of Education of the LEA s in the region. An initial, informal approach was then made to a number of teachers to see if they would be willing to take part in this research exercise. These teachers included those who were known, to myself or colleagues, to be interested in the applications of microcomputers in schools, together with those teachers whose questionnaire returns indicated such an interest. With the agreement of the teachers, permission was then sought from the Heads of the schools concerned.

Teachers in some thirty schools took part in short, informal interviews about the use of computers in their departments and schools. These interviews allowed the particular interests of the teachers to be determined and a clearer picture of the use of CAL in the school to be established. Those teachers who expressed an interest in the use of CAL were then asked if they would be willing for their teaching to be observed on a number of occasions, both with and without the use of CAL.

While the principal object of the research was to look at computer use in the chemistry classroom, it was decided to spend a little time comparing this with other areas of the curriculum. The initial observations were, therefore, extended to include geography, history, physics and biology lessons in secondary schools and, also, the work of one teacher with the senior class in a primary school.

In choosing a representative sample, a number of factors were considered. It was felt that the teachers observed should cover the full range of CAL experience, from those whose first lessons using CAL could be observed, to those who felt that they used CAL as part of their normal routine. It was also felt that the schools involved should cover as wide a range of the population as possible. This would allow the observations to be made in a wide range of settings and so, hopefully, show the full range of computer-use current in schools at this time.

It was also recognised that teacher-styles vary and that the sample chosen should contain a range of observed styles. This range of styles was marked by different tendencies to use group-work, different degrees of open-endedness (in lesson structure and question style) and by differences in the balance between 'theory' and 'practical' lessons.

After discussions with colleagues, it was decided that six to ten schools and teachers would be an adequate final sample for this study and so, after further visits to observe lessons, a final group of ten teachers from eight schools was chosen which appeared to be representative of those situations observed.

It was, of course, realised that the chosen group was unlikely to be truly representative of the teaching population as a whole. The initial observation period was, by necessity, rather brief and the judgement of 'style' rather subjective. Furthermore, the group was chosen from those who expressed an interest and so, to some extent, was self-selected. As has been said earlier, expressing an interest at such an early stage of a new development would seem to indicate that these teachers were more innovative than their colleagues, who showed no such interest. Working with a group of self-selected, enthusiastic innovators hardly seems likely to guarantee generalizability (extrinsic adequacy). However, it was probably unavoidable at this stage of CAL-use: uninterested teachers cannot be forced to take part in such an evaluation. The data generated by the observations would, therefore, need to be treated with considerable circumspection if there were to be any attempt to generalise the conclusions.

On the positive side, it was felt that the data would show what could be achieved with limited resources and would show the types of CAL-use which produce beneficial modifications in pupil-behaviour. It was also likely that the data would reveal successful examplars of classroom organisation and management and appropriate role-models for teachers and pupils in the use of this new technology.

The Teachers

In addition to the points raised above, all the teachers involved in this study had at least five years experience of teaching and all had taught pupils throughout the age and ability ranges in their respective schools.

Teacher 1 taught chemistry in a Sheffield comprehensive school and had been using CAL in her teaching for two years prior to the observations. This use was typically once-a-term with the sixth form and once or twice a year with the fifth form. She had attended a short course on the uses of microcomputers in teaching in July 1979 and, at the time of the observations, was involved in the production of a CAL unit for the Schools Council project: 'Computers in the Curriculum'. The school was a mixed, 11-18 comprehensive with some 1100 pupils on roll. Teachers in the school felt that the catchment area gave the school a 'fairly average' pupil-population with, perhaps, a bias towards the less-able pupil. Initial observations showed that Teacher 1 maintained a formal whole-class teacher-exposition style in 'theory' lessons. Although group-work was the norm in 'practical' lessons, these, too, were teacher-centred with well-defined, closed tasks set.

Teacher 2 also taught chemistry in a Sheffield comprehensive school. Although she had had no direct experience of the use of CAL in school prior to the observations, she had attended a four-day course on the applications of microcomputers in teaching, in July 1982. She had, therefore, some knowledge of the range of CAL material available and of the operation of the microcomputers in her school. At the time of the observations, the science department in her school did not have a micro and the use of computers in lessons was, therefore, only possible by prior arrangement with the computer studies department. The school was a mixed, 11-18 comprehensive with some 1800 pupils on roll. It was felt to have a 'very average' intake, though without the extremes at either end of the ability scale. The school presented a very formal, traditional picture of its 'educational standards' to the general public. In lessons, however, (at least in the science department) a much less formal, investigative approach was used. This was reflected in the work of this teacher, who appeared to adopt a more open-ended approach than most of the observed teachers.

Teacher 3 was Head of Chemistry in a Derbyshire school. He had considerable experience of the use and development of CAL material and had both attended and taught on several courses in this field. His approach to teaching was very much pupil-centred and, even in 'whole-class' situations, he was willing and able to respond to the needs of individual pupils and to allow pupil-initiated lines of enquiry to be followed. At the time of the observations, there were six microcomputers permanently stationed in the chemistry laboratories and some thirty programs were available for use in chemistry, many of which had been written by pupils in the school to tackle specific problems in chemistry. Teacher 3 also organised a thriving 'computer club' in the school. The school was a boys' 11-18 comprehensive housed in what had been, until a few years ago, the boys' grammar school. The school still benefitted from the 'parental choice' system operated in the area and, with a school roll of some 1100 boys, had nearly 120 pupils taking chemistry at 'A'-level. The school population seemed to have a higher proportion of the more able, more motivated pupil than other schools in the area.

Teacher 4 was Head of Chemistry in a Sheffield school. He had begun to use CAL in his teaching in the two terms before the observations. His experience was limited to two CAL units produced by the Schools Council Computers in the Curriculum Project and a short program which he had written himself - "to help with 'percentage of water of crystalisation' calculations". He had attended the same course as teacher 2 in July 1982. The school was a mixed, 11-18 comprehensive with some 1000 pupils on roll. It was classed as a 'special priority school' (SPS). The school population had markedly more of the less able, less motivated pupil than would be considered 'average' and only a relatively small proportion of pupils would be expected to achieve an 'O'-level in any given subject. The teacher reported that he 'tried to do as much practical as possible'. Initial observations tended to support this: he used a mixture of 'open' and 'closed' activities in both 'practical' and 'theory' lessons and he minimised whole-class activities.

Teacher 5 had been Head of Chemistry in an ILEA school before moving back to the Sheffield area shortly before these observations took place. She had had no experience of using computers before coming to this school. However, two other members of the science department were keen computer-users and had encouraged her to look at some of the available software. She had used the computers on two occasions since joining the school. The school was a mixed, 13-18 comprehensive in Derbyshire. It served a largely middle-class area and its pupil-population tended towards a high proportion of the more able, more motivated pupil. The approach to lessons was fairly formal, with great stress being laid on examination success. The teacher leavened a formal, teacher-centred, whole-class approach with a number of pupil-centred, open-ended activities.

Teacher 6 was Head of Chemistry in the same school as Teacher 5. He had considerable experience in the use of computers and had been using them regularly in school for two years before these observations. He was involved in the production of software for the Computers in the Curriculum project and for the Derbyshire Software Library. His teaching was very much teacher-centred, with a strong emphasis on whole-class, closely directed, 'closed' activities.

Teacher 7 taught chemistry in the same school as Teacher 2. He had rather more experience of the use of computers and was involved with a project, based at the University of York, looking at the use of micro s to monitor laboratory experiments in schools. Much of his teaching was based on 'teacher-exposition' to the whole class, although some pupil-centred, more open-ended activities were observed.

Teacher 8 taught chemistry in a Sheffield school. He had had no previous experience of using computers, but had become interested through talking to one of his colleagues who had worked on some of the early 'Computers in the Curriculum' biology software. The school was a mixed 11-18 comprehensive, with some 1000 pupils on roll. The school provided a pleasant working environment for the pupils with modern, well-equipped laboratories. The school population was felt to be biased towards the better motivated pupil: as one member of staff put it, "We get less of the bottom end, rather than more of the top". Observation showed that, while much of his teaching was based on 'teacher-exposition to the whole-class', he was willing to follow pupil-suggested lines of enquiry when and where these arose.

Teacher 9 taught physics in a Sheffield school. He had considerable experience of the use of computers in schools and was especially interested in their use in control technology, the monitoring of experiments and the simulation of experiments. Much of his teaching was based on individual or small-group work. However, the tasks set tended to be closely teacher-directed with clearly defined ends (from the teacher's viewpoint). In practical work, however, he allowed more opportunity for the pupils to follow their own lines of enquiry, within the limits of the equipment provided. The school was a mixed 11-18 comprehensive with 1800 pupils on roll. At the time of the observations it was undergoing a marked change in its catchment pattern due to an extensive housing development close to the school and the loss of many children to a new school nearby. It was now taking in an increasing proportion of children rehoused from the inner-city areas.

Teacher 10 taught the senior class in a Sheffield middle school - the pupils were equivalent in age to the first-form of an 11-18 comprehensive school. Apart from 'keynote' lessons, the children worked in small-groups in what approximated to an 'integrated-day' structure. This left considerable scope for the children to pursue their own particular interests, subject to them maintaining an acceptable rate of progress in all areas of the curriculum. The teacher had been using a Sharp MZ80K micro with her classes for two years. However, the supply of software was very limited and this restricted the usefulness of the micro. The school drew almost all its children from a large council-housing estate built shortly after the Second World War. The staff felt that there was a good mix of ability in the school, but that they had fewer of the brighter children.

63 observations of these 10 teachers have been included in this study, ranging in number from 10 lessons by Teacher 3 to 4 lessons by Teacher 10.

Selection of CAL Material

Much of the initial work involved in the B.P. Fellowship which funded this project was concerned with the development of software for schools. This involved the author in designing and writing CAL material and, more importantly, in working with groups of teachers interested in developments in this area. These meetings provided many opportunities for discussing current developments and for making school-based contacts. It rapidly became clear that teachers wanted software to support and extend work with which they were currently involved. While the teachers were willing to trial any available materials, it was felt that this would be a rather artificial situation if the software involved did not fit naturally into the pattern of teaching within a particular school.

Consequently, during the initial visits to schools, the choice of software available was discussed in detail with the individual teachers. The supply of software posed little problem for those teachers who were using CAL regularly, as they had built up their own supply of material, including programs written by themselves, by colleagues and by pupils. The wider use of many of these programs, however, was restricted by the lack of written support material and by the machine-dependent nature of the programs: with the Authorities standardising on different machines, units developed, for example, on a 'PET' by a teacher in Derbyshire could not be used on the 'Apples' available to teachers in Sheffield schools.

However, for the 'regular users' within a given authority, it was found that programs developed in one school rapidly circulated to other schools and these programs formed a valuable source of CAL material. Developers, in general, were very willing for their programs to be used by others.

With the 'new CAL users', however, assistance had to be given in finding suitable material for their use. All the available CAL programs were considered, both those already published and those which could be used in pre-publication trials form. It became clear, during the discussions, that any attempt to prescribe (or proscribe) particular types of software would be counter-productive and that the teachers wanted software which would fit in at an appropriate point in their existing teaching syllabuses. It was also apparent that prescribing the programs to be used would have limited the number and variety of classes seen or would, in some cases, have resulted in the topic being taught 'out of sequence', i.e. not in the order of topics normally taught by a particular teacher. In the end, a mutually-agreed selection was made of those units which would fit naturally into their normal teaching sequence.

Allowing the teachers a free choice of programs increased the number of different programs seen and, probably, increased the age and ability range of the pupils involved in the study. While this 'free choice' allowed an examination of how teachers with similar styles reacted to differing programs, it restricted the number of occasions on which the same program could be seen in differing settings. It was felt, on balance, that the benefits of allowing a free choice, so keeping the setting as naturalistic as possible, outweighed the disadvantage of some loss of 'control' groups.

In the end, a wide range of software was used, ranging from published simulations of chemical processes to programs written in school, designed to help with simple calculations. Many, probably the majority, of the programs used were trials versions of programs being developed for the Computers in the Curriculum project. Throughout this study, the programs used are referred to by a NAME in upper case: these names and details of the sources of all the CAL-units used in this study is given in Appendix 2.

DISCUSSING THE OBSERVATIONS

Lesson Structures

Preliminary observations in this study showed that a common basic strategy was adopted by teachers in structuring their approach to lessons. In broad terms, lessons consisted of:

> a relatively short introductory stage, concerned with managerial problems and with establishing a starting-point for the lesson;
>
> a central, key-section, concerned with the transfer of the required information, gains in experience and changes in attitude;
>
> a final, summary/consolidation stage, concerned with assessing and/or confirming progress, setting further work and giving pointers to future activities.

However, when one began to look more closely at the details of lesson strategies, differences became apparent, both within the various stages of a lesson and in the detailed relationship between one stage and the next. With the introduction of the micro into the classroom, differences had arisen in the organisation and management of the lessons and in the teaching and learning styles adopted. It is with these changes and their causes that this study is concerned.

In order to facilitate the discussion of observed teaching strategies, an acceptable means of conveying the 'flavour' of a lesson was needed, preferably in terms which the experienced science teacher would understand. For the present purposes, it was found convenient to classify lessons, somewhat crudely, as based in 'Theory', 'Practical' or 'CAL' work. It must, of course, be recognised that any given lesson may contain elements of any or all of these three aspects. In practice, it was found that one aspect usually dominated a lesson and it is this dominant aspect which will be referred to in the following discussion. As a guide:

> 'Theory' lessons are those concerned with the transmission of information or ideas which do not make significant use of immediate practical experience and do not involve significant use of the computer.
>
> 'Practical' lessons are those in which the major portion of the lesson is devoted to experimental work by the students or in which the major theme of the lesson is illustrated by the students' experiments.
>
> 'CAL' lessons are those in which the use of the computer is central to the main theme of the lesson. This would include the use of the computer to illustrate theoretical points or to simulate an experiment.

A fourth type of lesson is well-known: 'Demonstration' of an experiment by the teacher. This would seem to be a hybrid of theory and practical lessons in which pupils gain vicarious experience of the particular 'practical' procedure. However, it did not occur during the series of observations made in this study.

An examination of some early SCANs revealed a superficial uniformity in the lesson structures used by the teachers involved in this study. This is not to say that an individual used the same style in every lesson, rather that the group as a whole tended to use similar styles for theory and practical lessons. The teachers had well-established ways of dealing with these lesson-types, but not with CAL. CAL was relatively new and was used to replace or supplement both 'theory' and 'practical' topics. This allowed comparisons to be made between the types of lesson structure and interpersonal interactions used in theory, practical and CAL-based lessons.

CAL-Based Changes

In examining the changes which using a computer brought to a lesson, it was felt necessary to look at three principal areas:

i) how teaching and learning strategies changed when a computer was used;

ii) how these changes in strategies affected the interpersonal tactics used by teachers and pupils;

iii) the extent to which program design or type affected the teaching and learning strategies used.

With such a complex area as teaching and learning and the interpersonal interactions involved, an individual study such as this could only hope to discuss particular cases and to illuminate areas of possible general significance. In Chapters 4 and 5, data available from the lesson SCANs and from transcripts will be used to illuminate the changes which occurred and to discuss their importance in the teaching and learning process.

Chapter Four

The Analysis of the Observations

In this chapter the data gathered in the series of lesson observations will be examined in detail. The data consist principally of the SCAN records and transcripts of sound and/or video recordings of individual lessons. It would not be profitable to attempt to include all the data generated as there is, inevitably, much repetition of ideas and structures when lessons are examined. Instead, the data will be summarised so as to illuminate the underlying pattern of events and to enable a discussion of their importance in the general classroom situation.

A COMPARISON OF LESSON STRUCTURES

To illustrate the ways in which lesson structures were observed to change when CAL was introduced, we will look in some detail at the work of four of the teachers involved in this study. (These are Teachers 1 to 4 mentioned earlier.) These teachers are felt to be representative of those observed and their schools, between them, have the full range of pupils.

The introduction of the micro produced differences in the lesson stuctures which were apparent at all levels, not only for different teacher/class combinations but also for the same combination in differing settings. While each teacher showed his/her own individual bias towards a particular style, they all modified that style to suit the prevailing circumstances.

Changes at the Activity Level

A comparison of the proportion of time spent in individual and small group work in the three basic lesson types - 'CAL', 'Theory' and 'Practical' - revealed a striking change in lesson structure. Introducing CAL into an otherwise theory-based lesson appeared to increase significantly the amount of small group or individual work. Table 4.1 compares the percentage of time devoted to individual or small group work in a series of lessons given by the four teachers.

Teacher	Lesson type		
	CAL	Theory	Practical
1	75	20	63
2	73	26	58
3	31	0	47
4	55	3	36

Table 4.1

Percentage of Time in Individual or Small Group Work

$X^2 = 30.9 \qquad p < .001$

The table shows that, in any particular lesson category, there was a wide variation in the time allotted to small group work by the different teachers. This was seen as being a reflection of the preferred teaching style of the individual teacher. Also, as one might expect, for any individual teacher, there was much less small group work in 'theory' lessons than in 'practical' lessons. More significantly, the figures for the 'CAL' lessons were, in all cases, much closer to the figures for 'practical' lessons than to those of 'theory' lessons.

This similarity becomes potentially more significant when one considers that most of the topics dealt with in the observed 'CAL' lessons would otherwise have been covered in 'theory' lessons. For example, three of the lessons used a simulation of the Contact Process for the manufacture of sulphuric acid, another used a game intended to teach the ideas underlying the formation of chemical formulae and yet another used a simulation of various 'rates of reaction' experiments, some of which could not be performed in the school laboratory. All of the teachers involved felt that the use of a computer to replace or enhance a 'theory' lesson was beneficial: the teachers said "it makes it [the theory] more real" and "they can try different ideas out for themselves" and "they really get a feel for how it works".

The increase in time spent in individual or small group work in 'CAL' lessons, compared with 'theory' lessons, seems to support the view that the computer can change the role of the teacher and allow him/her to move round the class in a supportive role: giving advice and help, prompting new ideas and checking the understanding of established concepts. When 'practical' lessons are compared with 'theory' lessons, they also show a higher percentage of time spent in individual or small group work, possibly for similar reasons - once the practical task has been explained, the teacher is, again, freed from the role of task-setter.

There is also a significant change in the type of activity taking place in the three types of lesson. Task-related pupil-pupil dialogue was virtually absent in the 'theory' lessons, whereas it played a significant part in both 'CAL' and 'practical' lessons. This, again, is seen as a result of the changed structure of the lesson and as indicative of a move away from a traditional teacher-centred approach towards a more informal pupil-centred structure.

Changes at the Episode Level

Differences are also apparent at the episode level, where in most cases the SCAN records show a greater number of (shorter) episodes in lessons involving CAL or practical work. Table 4.2 shows the average length (in minutes) of the episodes in which the teacher participated for the same series of lessons used for the previous table.

Teacher	Lesson type		
	CAL	Theory	Practical
1	1.9	3.0	1.6
2	3.3	5.0	3.1
3	1.8	2.8	2.6
4	2.5	3.0	3.3

Table 4.2

Average Length of Episodes (in minutes)

$X^2 = 31.34 \quad p < .001$

The changes in the length and number of episodes reflect the differences in the structure of the various lesson types. Both the increase in small group work and the alleviation of the teacher's role of task-setter encourage the teacher to move from one group to another, discussing specific problems and strategies with each individual or group.

The nature of the episodes themselves is also changed with, for example, the number of 'explaining' and 'initiating' episodes being reduced, while the number of episodes of 'coaching' and, within a group of pupils, of 'arguing' or 'searching' is increased. Indeed, the SCAN records show that, for small group work activities in lessons involving CAL, 'coaching' forms the basis of the great majority of teacher-initiated episodes.

With the increase in group-work, there is inevitably an increase in pupil-led episodes and, for much of the time, the majority of pupils in the class are not directly controlled by the teacher: they are in control of their own learning and able to make decisions which materially affect the outcome of the episode. This represents a marked change from the conventional view of school lessons and must be seen as one of the ways in which the use of CAL can change teaching and learning strategies. These changes will be illustrated later, in the discussion of individual lessons.

Changes at the Event Level

Changes also occur at the most detailed level recorded in the SCAN - the event or remark level. Table 4.3 shows the proportion of some different question types used by Teacher 2, with a third-year middle-band chemistry group, for lessons with and without the use of CAL.

	Ratio of Question Types	
	Depth of Demand $\alpha : \beta$	Level of Guidance 1 : 2
CAL used	1.1 : 1	0.7 : 1
CAL not used	3.7 : 1	1.8 : 1

Table 4.3

Differences in Question Types

The figures quoted in Table 4.3 cannot safely be generalised as there are too many factors which may influence changes between one lesson and another. However, seven out of the ten teachers observed for this study showed similar trends in their use of questions, two showed no marked change and one reversed the trend, using more closed, less demanding questions when CAL was in use. While it seems likely that CAL is one of the factors influencing question-style, its influence may be variable, depending on the style of the program and the way in which it is used by the teacher.

Other changes found to occur at the event level were seen as a direct result of the changes in lesson stucture at the episode and activity level. Perhaps most noticeable was the simple reduction in the proportion of teacher-led events: in a group-work situation the teacher could only work with one group amongst many, so pupil-led events were almost certain to predominate. The same was not necessarily true of individual work, where teacher control of the events was often as complete as in an exposition to the whole class, 'Ew', activity. This will be discussed in detail later (pp 161-170).

There were, however, a number of more subtle, tactical changes taking place in the detail of the teacher's actions. There was a marked tendency for the teacher to be less directive, to use more general examples and to make suggestions rather than to give instructions. The pupils also responded to the changed circumstances by adopting different approaches to learning. These changes can most easily be exemplified by considering some individual lessons.

Any changes in teaching strategy, such as those detailed above, are likely to be accompanied by changes in the details of the events on which the lesson is based. These tactical changes in the interactions between teacher and pupil and between one pupil and another were found to be widespread and seemed to imply a fundamental change in the approach to the teaching and learning of the topics affected. The change in approach was generally seen as beneficial and the extent to which CAL was an important agent of this change can be demonstrated by examining the work of individual teachers with their classes in a number of curriculum areas.

Two Approaches to a Problem

Occasionally, lessons arise which allow direct comparisons to be made between the use of a computer and a more traditional approach to a topic in the same lesson. One such lesson arose in the work of Teacher 5, teaching a topic on "industrial chemistry" in a 5th-year 'O'-level chemistry class.

Pupils were set the task of selecting suitable sites in Northern England and Wales for a range of industries, including oil and petrochemicals, iron and steel, ammonia synthesis and the manufacture of sulphuric acid. There were two approaches to this task: one based on a pencil and paper activity and one based around the computer.

Both tasks had the same objectives, both were subsumed into a single lesson-structure with broadly similar interactions between teacher and pupils and, in both cases, the pupils were presented with a similar series of tasks:

i) select an industry from a list - "Choose one you have studied recently or which you know something about";

ii) decide upon appropriate raw materials for the process;

iii) consider the sources and costs of transporting the required raw materials and on this basis choose an appropriate site for the industry.

This lesson was felt to be particularly interesting because of the differences observed in the teacher-pupil and pupil-pupil interactions and the differences in the pupils' perceptions of the two activities.

The Pencil and Paper Exercise

The pupils were provided with duplicated outline maps of England and Wales on an A4 sheet, with the principal ports, roads and railways marked, together with the main geographical features (hills and rivers, coal and mineral deposits). They were also given a second sheet with the names of various industries printed in small circles.

Working in small groups, the pupils had to choose an industry and decide what raw materials were necessary and from where they could be obtained. They then had to decide which areas would be suitable for that particular industry, cut out the name of the industry and glue it onto the appropriate place on the map. In this way they built up a record of the sites occupied by the major plants in the industries concerned.

The CAL-based Exercise

The program, INDUSTRY, written by two teachers in the school, was a computerised version of the pencil and paper activity and was available through the Derbyshire Software Library for PET and BBC micro's. The pupils found no apparent difficulty in running the program or in understanding the "menu" presentation.

Both Commodore PET and BBC microcomputers were used in the lesson and it was left to the pupils to choose which they used. Pupils simply moved to whichever one which was free: there did not appear to be any group waiting for a specific machine. The "better" graphics on the BBC (high resolution graphics, giving a more accurately drawn map) seemed to make little, if any, difference to the motivation of the pupils nor to their interpretation of the results.

The basic program stages were as follows:

i) Title page and brief instructions.

ii) Menu of industries - "Choose one you have studied recently or which you know something about".

iii) Menu of raw materials - the program would not move on until an appropriate choice had been made.

iv) Display of the "weightings" given to the required raw materials - a high weighting meaning that it was important for the plant to be near the source of that particular material.

v) Display of map - pupils asked to enter the co-ordinates of their chosen site.

vi) Tabulation below the map of the sites chosen by the pupils and the scores awarded by the program. The scores were given as a percentage, based on the distance of the selected site from one of the "ideal" sites.

The pupils could repeat Step 5 until they were satisfied with their score and then return to Step 2.

The Work of the Teacher

After the initial introductory session, the pupils worked almost entirely in a small group setting. The teacher moved between the various groups in a series of "Coaching" episodes, acting principally as a facilitator. She discussed, with the pupils, their reasons for their choice of site and the way in which one decision affected subsequent choices. For example, the pupils were 'encouraged' to locate oil refineries near deep water ports and this, then, fixed the area in which a Haber Process (ammonia synthesis) plant would be situated.

While all 'coaching episodes' were fairly short, less than five minutes, it was clear that much more time was being spent in 'coaching' the groups working with the 'pencil and paper' activity - typically twice as long. Teacher statements tended to be more directive with the 'pencil and paper' groups. For example, when discussing the manufacture of aluminium, the teacher associated the need to import bauxite with the need for a big harbour:

T.	Where does it [bauxite] come from?	qα1
P.	Jamaica	/
T.	Yes. So you're going to need to put it near a big harbour.	aα1

This suggestion carried many hidden assumptions about the throughput of the plant and the bulk of the ore. By asserting the need for a nearby, large harbour, the teacher pre-empted one particular error, but she also removed the need for the pupils to discuss the problem amongst themselves. Such pre-emptive action was often found where the teacher apparently felt that otherwise the pupils would soon be making 'incorrect' decisions or be unable to proceed.

Teacher-direction was much less obvious when working with the CAL-based groups. In the following extract, the teacher moved to stand behind a group looking at chlorine production, silently observing the discussion.

P1. Where does salt come from?

P2. (Looking at map on screen) Wales isn't it? (actually Cheshire)

T. What else do we need?

P1. Electricity

P2. You can get it from that nuclear thing they have just built in Wales.

(Pupils decide to site brine plant above salt mines)

T. What else would you need to take into account if you were doing this for real?

P1 People

T. Anything else?

P1 Transport

T. Yes (leaves group)

In discussing the electrolysis of brine, the teacher made no direct connection between the location of the raw materials and the siting of the plant. Indeed, the pupils did not need to have such a connection pointed out: they were able to derive the connection from the information given in the program. The teacher did, however, introduce other possible factors, but left the group without giving any idea of their relative importance. It was left to the pupils to make their own decisions: the teacher was secure in the knowledge that the computer would provide some corrective feedback (albeit limited) if the wrong final decision was taken.

The Work of the Pupils

The pencil and paper version gave the pupils no information about the sources and properties of the raw materials - although they were advised to choose an industry they had studied - nor was there any means by which the pupils could judge their own progress. The lack of information slowed down the more able and encouraged guessing. The lack of immediate feedback also retarded progress and made heavy demands on the teacher's time which, in turn, reduced the value of the teacher intervention. It was felt that this type of problem generally reduced the effectiveness of the activity.

It was noticeable that the pupils preferred the computerised version of the task and that they appeared to get more satisfaction from the computer's percentage score than they did from the teacher's intervention (which was directive and qualitative). More importantly, there were several changes in the pupils' approach to the task:

i) they were able, without outside help, to try out variations in siting the industry;

ii) they were more vocal in their decision-making;

iii) they discussed, amongst themselves, the reasons for not getting a 100% score and took appropriate action.

In using the program, the pupils tried to use the weightings given to the raw materials as the basis for their choice - this was, in fact, sufficient for the "salt industry" example above. If, however, the pupils tried to decide on a site for an ammonia synthesis plant without first locating an oil refinery, then the weightings were not so helpful as no source of hydrogen had been established. This led to a certain amount of guessing, with the marks given by the computer being used to "improve" the guess. The guesses were not as random as one might have expected, probably because the pupils had studied the various process before. Realising that the hydrogen necessary for ammonia synthesis was produced at oil refineries, the pupils made informed "guesses" as to the location of the refineries and, therefore, at the position of the ammonia plant. This was made possible because feedback on the appropriateness of their decisions was given immediately and was no longer restricted to the times at which the teacher was available.

Summary

When discussing, with the researcher, the reason for including this activity the teacher said:

> "[We] want to introduce some industrial content into the course but we don't really know how much to do or how far they [the examining board] want us to go with the socio-economic stuff."
> "... we thought that doing it like this would make it more interesting - it's a bit dry otherwise."

Both the CAL program and the pencil and paper task considered only one part of the economic problem: location near to the source of the raw material; they did not consider the relationship to the market, nor did they take account of any environmental considerations. In the program, the weightings given to the "transportability" of the raw materials were rather simplistic. For example, electricity was rated zero: where the power was generated was considered irrelevant. This may be a fair approximation for many, if not most, industries, but should not have been acceptable for the production of aluminium.

Such problems, however, did not prevent the pupils getting a reasonably accurate view of the actual locations of the chemical industry in this country. Programs which gave a more complete view of the problems of siting were available, but were not specifically concerned with the chemical industry and were, therefore, felt to be inappropriate by the staff of the school. To have given a more complete picture would probably have necessitated substantial changes in the earlier part of the course and this was unlikely to happen while the teachers were unsure about "how far they [the examining board] want us to go with the socio-economic stuff." A different approach to the 'siting' problem was found in the work of Teacher 2 with the DALCO program: this will be discussed later.

Practicals and Simulations

Many similarities have been noted between the strategies adopted in 'practical' and 'CAL'-based lessons; at the tactical level, however, a number of important differences were found. These differences will now be illustrated by examining the work of Teacher 4 in two lessons concerned with teaching "Rates of Reaction". The group of 25 fifth-year pupils taking part represented the upper end of the ability scale for their school: between a half and two-thirds of the group were expected to gain an 'O'-level pass, with the rest obtaining "good" C.S.E. grades.

The Practical

In this session, the pupils investigated the effect of changes in temperature on the rate of the acid/thiosulphate reaction. The reaction, as carried out in this lesson, is very much a standard experiment and is well described in most elementary text-books. The pupils had previously carried out experiments to illustrate the effects of concentration and of particle size on the rate of various reactions. Again, standard text-book methods had been used. The class had, therefore, some expectation of what was involved and of the kind of results to be expected.

The lesson showed clearly the four stages involved in most 'practical' lessons:

i) Revision of relevant previous work.
This allows the teacher to establish control and to introduce the topic for the lesson.

ii) Instruction in today's practical.
This is usually, but not always, a step-by-step account of what to do and what to look for.

iii) The practical itself.
This includes much pupil-pupil dialogue, together with coaching episodes by the teacher. It almost invariably includes short teacher-expositions, to the whole class, in which the teacher takes up points of general interest which have arisen in the work of individuals.

iv) The summary.
In this final part of the lesson, the teacher attempts to clarify the issues raised by the practical, to explain what should have happened and to give clear pointers as to the expected 'conclusions'.

While stages (i), (ii), and (iv) were very much teacher-centred, they were very much shorter (in total) than stage (iii). This is generally the case in practicals, where the setting-up of the apparatus and actually performing the experiment take up much of the available time. This teacher-dominance is clearly illustrated in the SCAN: no examples of pupil-initiated events were found outside stage (iii). Within stage (iii), the teacher was kept very busy giving advice and reassurance and the pupils depended heavily on his 'checking' and 'coaching' episodes.

The Work of the Teacher

The lesson began with a typical introduction in which the teacher used a mixture of "gambit" and "managerial" statements to settle the class and to focus their attention on the work in hand.

> T. Right! Can you open your books at that homework first of all. ..... Right! ... Are you ready? m

> T. I just want to go over the answers to these questions before we start today's experiment. g

The teacher then went on to talk about the homework, using the blackboard to illustrate a series of assertions about the answers (to the homework), together with any confirmations and/or rejections of the answers supplied by the pupils.

During the five minutes this "revision" occupied, there was little overt activity expected of the pupils, other than checking their own answers against those being given by the teacher. Two checking questions were used by the teacher, one being:

T.	Part 1 asks "Is the electrolyte solid, liquid or in solution?"	aα1
	Come on, what's the answer?	ch
P.	Liquid.	aα1
T.	Andrew?	ch
A.	Liquid.	aα1
T.	It's molten, yes, or liquid.	cf

This passage illustrates the way in which an apparently simple event (in this case repeating the checking question) can have a 'hidden' role in maintaining discipline within the class. While SCAN has no formal notation for recording vocal stress patterns, annotations can be made where necessary to indicate such influences.

After the opening 'revision' episodes, the teacher moved the lesson firmly into the 'initiation-instruction' spectrum by detailing the purpose and method of the experiment to be performed by the class. The first of these two episodes (part of which is shown below) was primarily instructive in nature: consisting mainly of the teacher making a series of assertions concerning the details of the experiment and the reasons for some of the procedures adopted.

T. We've had a look at two of the factors which affect reaction rate in some detail now. $a\alpha 1$

T. We've had a look at particle size ... and the last one we did ..... was the effect of concentration. $a\alpha 1$

T. Today we're going to look at the third factor in detail - we're going to look at the effect of temperature. $a\alpha 1$

This was followed by a further episode concerned mainly with the initiation of the practical itself. In this episode the teacher used managerial statements, to divide the class into groups, and instructional statements detailing the experimental procedure. For example:

T. You need to take 50cm^3 of the sodium thiosulphate solution; pour it into a conical flask. $i\alpha 1$

T. I want you to heat it up to a temperature I am going to give you. $i\alpha 1$

Once the practical was underway, the teacher was able to move round the classroom, from one group to another. The feedback needed by the teacher did not appear to arise naturally, but as a result of either the teacher making a positive intervention into the work of the group or a pupil requesting help. In this lesson, the majority of such episodes were inaudible to the observer, but those which were audible could clearly be classified as

'Coaching'. Again, they tended to be concerned with the practical details of the experiment, rather than the underlying chemical principles. Only a short time was spent with each group and this pressure on the teacher to move on to the next group might have been a major factor in limiting the depth of the discussions.

It was only at the end of the lesson, after the apparatus had been put away, that the teacher attempted to bring out the major points 'illustrated' by the practical. This began as an 'Exposition' to the whole class, with the teacher using a question-and-answer technique to assess what the pupils had learned and to guide their conclusions in the right direction. This was, however, quickly interrupted by the end-of-lesson bell.

The Work of the Pupils

Throughout the lesson, the general atmosphere was one which allowed the pupils to work, although there was little pressure on the individual child to attain specific goals. The pupils worked in groups of three or four: each group had to carry out the experiment at a given temperature and record their results on an OHP acetate so that all the class could share the work. Within the given parameters, however, each group had considerable freedom of action. For example, one group had to carry out the reaction at 40°C; it was left to the group to decide who organised the apparatus, who took the notes, where and how quickly they worked etc. This movement of control of a lesson from teacher to pupil is felt to have important consequences for the teaching and learning process.

The pupils, working in their groups, were able to discuss the work in hand: these discussions were fairly simple in structure and low in demand as far as the interpretation of the experiment was concerned. As was found in many other lessons, pupil-talk during the practical work tended to concentrate on the technical details of the experiment, to the exclusion of the underlying chemical principles. The following passage illustrates this point.

P1	Is it 60?	ch	(temperature of solution)
P2	That's it.	aα1	(looking at thermometer)
P1	Is it 60?	<u>ch</u>	
P2	64.	aα1	(P3 then reads temp.)
P3	It's O.K.	aα1	
P1	Are we first?	ch	(i.e. should we be first to use the OHP?)
P2	No, it's the lads.	aα1	
P3	It's coming down now.	aα1	(checking the temp. again)
P1	It's meant to.	aβ2	

While such pupil-pupil dialogue is necessary if the lesson is to run smoothly, it is not indicative of any real understanding. That is not to say that the pupils do not learn from their practical experience, but rather that whatever learning is taking place is hidden from the observer and/or the teacher. Perhaps just as importantly, the learning of one individual is hidden from other individuals in the group: it is not shared as readily as might be expected, given the co-operative nature of the work.

Pupil-initiated events occured mainly at the most simple levels and were invariably restricted to points of practical procedure. This limitation of pupil-talk was commonly observed in practical lessons and would seem to be associated with the way in which the lessons were organised and the type of work expected of the pupils.

The Simulation

In the next chemistry lesson, the class continued working on the same topic - rates of reaction - but this time with the use of a microcomputer. The program used was the original microcomputer version of DECOMP. The SCAN revealed broadly the same lesson pattern as in the previous, practical-based lesson:

i) teacher-exposition to the whole class to establish control and revise any necessary work from the last lesson;

ii) further exposition to introduce the main activity for the current lesson;

iii) small-group work with coaching episodes by the teacher, pupil-pupil dialogue and occasional interruptions by the teacher for whole-class expositions;

iv) a final teacher-exposition, 'Ew', activity to recap the main events/ideas of the lesson.

There are, however, some differences in the detail of the SCAN which are felt to be important.

The Work of the Teacher

From the beginning, the teacher expected the pupils to participate more actively in the lesson. Once the pupils were settled, the teacher demonstated the program (with a pupil at the keyboard) and explained the structure of the lesson. In doing so, he asked the pupils to interpret what they saw on the screen and to relate this to their own experience of the practical work they had done in the last few lessons. The majority of the questions used and explanations offered by the teacher were classified as 'β1' in this stage of the lesson: the introduction to the practical lesson contained only 'α' events.

During stage (iii), the teacher moved from one group to another in much the same way as in the practical lesson. However, with no need to 'coach' the pupils in manipulative skills, the teacher was free to concentrate on the interpretation of the "results" of the simulation and on discussing possible values for the next simulation. At various stages the teacher was heard discussing why the size of the catalyst particles has an effect, why the upper temperature limit was not 100°C and the mechanism of the Bombardier Beetle (quoted in the program notes).

The Work of the Pupils

In addition to the more active role of the pupils in the introductory stages of this lesson, important differences were noted in the types of pupil-pupil interactions ocurring when stage (iii) of this CAL-based lesson was compared with the equivalent part of the earlier practical-based lesson. The following apparently simple example was typical of the CAL-based lesson: a group of students had entered the conditions used in their reaction and were watching the computer draw a graph of the volume of oxygen against time.

P1	That's it.	aβ2
P2	How do you know it's finished?	qβ3
P1	Because the volume's not going up any more.	/

If one considers the type of question which was predominant in the practical-based lesson (simple requests for information, such as "How hot is it?"), then the difference in demand is immediately apparent. In this latter case, the questioner was asking a fellow pupil to explain her interpretation of the results, rather than simply to supply a particular value or result.

Such an exchange provides the observer with prima-facie evidence of the pupil's involvement in interpreting the data and of the extent to which the situation is seen as 'real'. The pupil related the marks on the screen directly to the volume of oxygen: she did not simply say 'the graph is not going up' or 'It has stopped changing'.

Summary

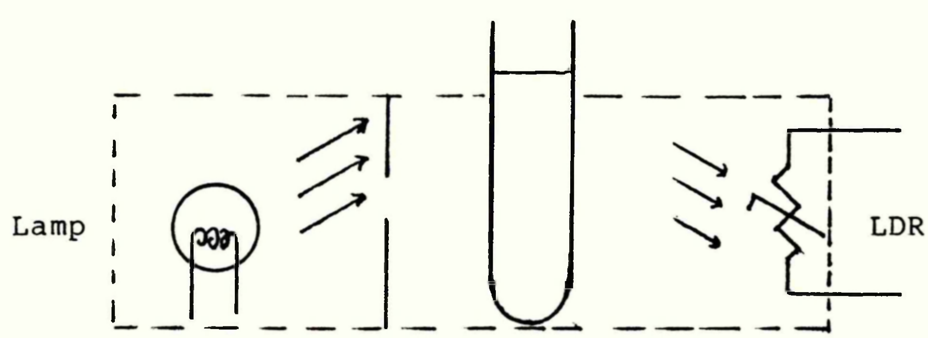
The similarity between 'practical' and 'CAL'-based lesson-tactics rests on the same group-work structures being employed. The differences in the types of interactions arise from the differences in the type of work undertaken by the groups. In both cases, once the task has been initiated, the teacher is free to work with individuals and/or groups.

The ability of the teacher to 'overhear the child's thoughts' is a crucial step in understanding which stage the individual pupil has reached and the type of difficulties s/he may be experiencing. By encouraging and supporting the type of vocalisation discussed above, the computer can provide the teacher with insights which would be unavailable in most normal classroom activities.

A somewhat different application of the computer was its use in measuring and recording the data generated in experiments. At the time of the observations, the use of a computer to monitor experiments in school laboratories was very much in its infancy and in only two of the lessons observed was the computer used for data capture. Teacher 3 and Teacher 7 had both, independently, developed very similar sets of apparatus for use in 'rate of reaction' experiments. As was mentioned earlier, determining the effect of aqueous thiosulphate concentration on the rate of the acid/thiosulphate reaction is a standard school experiment: the apparatus produced enabled the computer to measure the time taken for this reaction to produce a fixed (arbitrary) degree of turbidity.

The Apparatus

Both sets of apparatus were based on a lamp and light-dependent resistor (LDR) arranged in a light-proof box so that a test-tube could be stood in the light path between the lamp and the LDR.



Teacher 3 used the apparatus with a BBC micro whilst Teacher 7 used his apparatus with an RML 380Z. The software, written by the teachers, was similar as far as the user was concerned: the initial concentration of the thiosulphate solution was entered at the keyboard, the 'clock' was started when the user pressed a key and the computer measured the period until the light-level fell below a preset limit. The time taken, in seconds, was displayed and its reciprocal was calculated and displayed. A point was then plotted on the screen corresponding to 'concentration' on the vertical axis and '1/time' on the horizontal axis. A 'good straight line' could be easily obtained and both teachers felt that this would help the pupils overcome some of the difficulties inevitably encountered in 'rate of reaction' experiments.

The Work of Teacher 3

In the lesson observed with Teacher 3, a fourth-year 'O'-level class was working on the series of experiments commonly used to illustrate the factors which affect the rate of reaction. The acid/thiosulphate reaction was used to illustrate the dependency of rate on temperature and on concentration and, in the latter case, the computer was also available in the laboratory.

The lesson followed a typical practical-lesson pattern, as described earlier, and the computer was not used until the latter part of the lesson. After the class had completed their practical work, the teacher collated all their results on an OHP so that they could compare results and "fill-in any gaps" in their tables of results. The pupils were asked to sketch graphs of "concentration against 1/time" and it became clear that the results were sometimes far from the linear relationship expected. The teacher had expected this lack of linearity. Indeed, his rationale for the use of the computer depended upon it.

The teacher used an 'exposition to whole class' activity, with the computer, to encourage the pupils to think about the sources of error in their own experiments. Starting from the expected shape of the graph, he chose a particular example:

T.	Peter, why didn't you get a straight line?	qβ3
P.	..... the concentrations weren't quite right.	✓ h
T.	Which did you use?	ch
P.	0.1, 0.5 and 1.	aα1
T.	Who else used those?	ch

He then went on to show that other groups using the same stock solutions had got different results. After a short discussion of the methodology, the teacher brought out the idea that judging the end-point of the reaction can be difficult and that the difficulty can vary with how fast the reaction is going:

T.	How did you know when to stop the clock?	qα1
P.	When you couldn't see the cross.	/

T. Does it disappear suddenly, or does it fade? 9dl

P's. (Quick.
(It varies. /
(It just goes.

He also introduced the ideas of errors in timing and recording the results.

He then introduced the idea of using the computer to take the guess-work out of judging the end-point. With the help of some of the pupils, he ran the experiment at five different concentrations using the computer to measure the time interval, calculate 1/time and draw a graph of the results. While the reactions were running, the teacher passed a duplicate piece of the apparatus around the class and explained how it worked.

It should, perhaps, be emphasised that the pupils had just completed the same set of experiments themselves earlier in the lesson: the experimental procedure and the expected results were fresh in their minds. Their collated results were still displayed on the OHP and they were able to compare these with the computer-measured timings.

The whole activity took less than twenty-minutes and, having seen the apparatus and the 'straight line' produced by the computer, the pupils appeared much more satisfied that 'good' results were possible and that 'the reaction worked'. The pupils took an active part, showing interest in the workings of the apparatus and raising points about the need for a light-proof box and the reliability of the cell in measuring light intensities.

The Work of Teacher 7

In this session the apparatus was used with a lower-sixth chemistry class studying the 'rates of reaction' section of their 'A'-level syllabus. The class had done some practical work on 'rates' in earlier lessons and were presumed (by the teacher) to be familiar with the acid/thiosulphate reaction. The lesson was set in a classroom, not a laboratory, and the teacher had brought the necessary chemicals, apparatus and computer to the room for the lesson.

The lesson opened with an 'Ew' activity in which the teacher explained what the hardware was supposed to measure and outlined its mode of operation. He then made a series of assertions about the reaction itself and what could be derived from the measurements of concentration and time obtained in the experiments. There was no apparent pupil-response, nor did the teacher appear to expect any: all the teacher talk in this period consisted of series of explanations and assertions.

With the group of eleven students sat around the monitor, the teacher demonstrated the experiment, using five different concentrations of thiosulphate. While each reaction was taking place, the entire group sat in silence: the teacher neither asking questions nor making any attempt to assess the understanding of the pupils. These periods of silence lasted from less than one minute to more than five minutes. The points plotted on the screen, as the program progressed, were very small and could not be seen by all of the pupils (nor by the observer) and the teacher had to point them out as they arose. There was no active participation by the pupils in this lesson and, therefore, no way of judging their understanding.

This process took some thirty minutes of a fifty-minute lesson: the rest of the lesson was devoted to the teacher dictating notes to the pupils.

Summary

The potential of this type of computer use is, undoubtedly, great but the extent to which it will change laboratory practice obviously cannot be assessed from two observations. The observations were, nevertheless, felt to be interesting in that they point to one way in which interested teachers can improvise and develop new ideas for use in the school classroom.

The contrast between these two lessons provides a particularly clear illustration of the way in which the personality and style of a teacher can produce very different effects in a lesson, even when the content and support materials are very similar. The active involvement of the pupils is essential if the teacher is to obtain adequate feedback about their grasp of the topic.

Variations on a Theme

In the last section the work of two teachers on a common practical/CAL theme was examined. Differing styles are, of course, also found in 'theory' lessons and in the 'CAL' sessions which support or replace them.

Teachers 1, 2 and 3 were observed, at different times, using CONTACT with classes studying the manufacture of sulphuric acid. The manufacture of the acid, of course, cannot be undertaken in class, although the basic steps in the reaction can be demonstrated by the teacher. Nevertheless, some understanding of the process and a knowledge of the actual conditions used was a requirement of many CSE and GCE 'O' and 'A'-level syllabuses. The teachers saw the program as allowing their pupils to develop 'a feel' for how the process works and for the need to compromise 'ideal' chemical situations and accept less than 100% conversion.

The Program

The program dealt, primarily, with the conversion of SO_2 to SO_3. It allowed the user to control the temperature, the pressure and the composition of the reaction mixture and to select the presence or absence of a Vanadium V Oxide catalyst. The effects of these variables on the reaction and their impact on the cost of the sulphuric acid produced, was dealt with, by the program, in three sections: one dealing with the rate of reaction; another with the equilibrium conditions; and the third with producing a compromise between the conflicting demands of rate and equilibrium, whilst at the same time making a profit and avoiding too much pollution of the environment. Undoubtedly, it was the third section which created the greatest interest amongst both pupils and teachers.

The Setting

The backgrounds of the three classes were rather different as was the computer provision available:

Teacher 1 worked with a lower sixth, 'A'-level class of seven pupils. Two Apple II micro s were available in the laboratory.

Teacher 2 worked with a fifth-year "bottom set" CSE class of 28 boys and girls. Seven Apple II micro's were available in 'the computer room' which was, in fact, a converted store room measuring about 8 feet by 15 feet.

Teacher 3 worked with a "bright" fourth-year 'O'-level class of 25 boys. Two PET micro s were available in the laboratory.

All the teachers were using the first microcomputer version of the program (which had been adapted from an earlier mainframe version): Teachers 1 and 3 supported this with their own, duplicated worksheets.

The Work of the Teachers

The teachers all used the same basic lesson structure: a brief introduction, small group work using the program and, finally, a summary period when the results of the various groups were compared. It was interesting to note that, although there was no overt attempt, on the part of the program designers, to make the program into a 'game', competition nevertheless developed between the groups of pupils. Teacher 2 deliberately introduced the idea of each group being a separate 'company' trying to make sulphuric acid cheaper than the others. The pupils then kept their ideas 'secret', as they strove to optimise the conditions to minimise their costs. This idea was not introduced with the other classes but a similar competitition arose to produce the cheapest acid. This time, however, the results were openly compared and criticised by the pupils.

The Work of the Pupils

The pupils were enthusiastic about the use of the program, particularly about the 'cost per tonne' provision. This made the program seem "realistic" and provided a good motivating force. Virtually all the pupil-pupil talk in these lessons was 'on-task' and the program encouraged the majority of the pupils to discuss the reasons behind the figures they suggested for the operating conditions of the plant. Perhaps the most difficult factor for the pupils to rationalise was the temperature: parts 1 and 2 of the program show that the rate increases with temperature, but that the equilibrium yield falls as temperature rises.

P1. Why has the yield gone down? qβ 3

P2. 'cause its hotter .... (pause) ... /
but we've made more per day. aβ 3

Before using the program, the pupils had not appreciated that the reaction did not **have** to approach equilibrium in order to be useful. By the end of the sessions, the sixth-formers and many of the brighter fourth-form pupils had clearly distinguished between the two effects of temperature and were able to deal competently with them. Some of the fourth year-pupils were heard 'coaching' others in their group about this point.

P. [When the temperature is increased] it goes faster, but less SO_2 reacts. You still get more out per day than if it was cold.

While such explanations may seem less than clear when written down out of context, they appeared to make sense to the pupils struggling with the problem. By allowing the pupils to vocalise their thought processes, the program can be seen to help the teaching/learning process, if only by providing the teacher with some insight into the difficulties the pupils are facing.

Several important 'practical' points were brought out by the pupils which had not been considered beforehand. For example, the pupils found an unexpectedly rapid rise in costs as pressure was increased: most were able to use the accounts generated by the program to trace this to the cost of electricity for the pumps. The pupils therefore tried reducing the pressure, which did, in fact, bring the costs down. A significant number tried to run the plant at 1 atmosphere pressure and the resulting zero production caused some consternation. They had, of course, neglected the '1 atmosphere' pressure at the outlet of the pipe. This 'error' occured in all three classes and none of the teachers had ever given this aspect any thought before using the program. Indeed, two of them admitted to making the same error when they first tried the program.

Summary

The results described in this section suggest that, whilst it is clearly important for the teacher to be familiar with the operation of the program, s/he must avoid the trap of using it only as a demonstration aid, showing what results can be achieved with the 'correct' figures. Such work would be little different than providing the figures from a text-book or worksheet. Similarly, s/he must guard against guiding the pupils too firmly along the 'right' direction.

The two unexpected results mentioned above (at high and low pressures) are examples of the way in which a good simulation can throw up important teaching points which might otherwise pass unnoticed or perhaps be taken for granted by the teacher. They also illustrate the importance of letting the pupils make their own mistakes with the simulation and letting them attempt to find their own remedies for them. 'Mistakes' in this situation are not end-points: there is no long pause until teacher marks the work. The feed-back is immediate and the initial error becomes the basis for an important learning step. This is seen as being much nearer to the way in which science actually progresses, building on negative results as much as on positive ones.

A similar range of lesson strategies and tactics was found to arise in curricular areas other than chemistry. The work of Teacher 9 in secondary school physics and Teacher 10 in primary school teaching was felt to be representative of the range of styles observed.

The Work of Teacher 9

The physics lessons of Teacher 9 showed the same differences between 'theory' and 'practical' lessons as had been observed in chemistry lessons. The practicals, however, were organised somewhat differently than in most of the chemistry lessons. In most of the observed chemistry practicals, the various groups in a class carried out the same basic experiment or set of experiments. Both the progress and the results of the experiments were discussed amongst the groups and a concensus was actively sought by the teacher and class. Restraints on the equipment in the physics laboratory often precluded this arrangement and the various groups worked on individual experiments within a common theme. The use of the computer could be seen as one activity within a circus of experiments - although it was also observed in use as a kind of 'electronic blackboard'.

The lessons observed were with a fourth-year 'O'-level/CSE set, working on the theme of 'light'. The pupils covered a series of experiments which involved fairly standard uses of ray boxes, lenses and mirrors. LENS, the program used, had been written by the teacher to provide interactive illustrations of the ray-diagrams associated with the experiments and, later, to provide a simple means of checking calculations.

For the more able pupils, the program provided a means of rapidly finding the answers to 'What if .... ?' questions which they could then check with the apparatus available. Such pupils were able to run through many of their own suggested situations in a much shorter time than was possible using conventional apparatus. The less able pupils in the class seemed to find the 'ray diagrams' produced by the program less easy to relate to the 'real' situation and were content to try the settings suggested by the teacher-produced worksheet. The main value of the program, at this stage, seemed to be not in initial teaching nor in a fully exploratory simulation, but in forming a bridge-head between the actual experiments and the formal 'ray-diagram' approach of their text-books. Those pupils who had experience of using the program seemed to have less difficulty in producing diagrams of their experiments. It may be that the diagrammatic response of the computer was helping the pupils to internalise the experimental data. The use of LENS in a whole-class drill-and-practice mode will be discussed, in some detail, in an examination of the pupils' responses to CAL (pp 167-170).

The Work of Teacher 10

There were, as might be expected, considerable differences in classroom organisation between the middle school and the comprehensive schools used in this study. Perhaps the two most striking differences were that the children in the Middle School were, essentially, taught by the same person for the whole year and that they worked in small groups as a matter of course. Very few lessons were taught to the whole class and the pupils followed a somewhat individualised scheme of learning. Thus, when the computer was used in class, it tended to be used by a group of children and not shared between the whole class.

From the teacher's point of view, the problems of managing a number of small groups in a class were much the same in middle and secondary schools. The teacher had to move her attention from one group to another and to respond to a variety of demands. The teacher-led episodes with a particular group were often 'coaching' and, within a group, the pupils would 'argue' whilst 'searching' for an acceptable solution in much the same way as their secondary school counterparts.

The reactions of the pupils to the use of a computer were also very similar in both types of schools. Observations of pupils using a simple drill-and-practice 'times-tables' program revealed very little dialogue taking place and the pupils seemed to work with the computer in much the same way as they would with a book of arithmetic problems. The only advantage of using the computer here was the immediate feedback as to whether they were right or wrong: the program involved had no remedial loops, but simply 'marked' the answer to each problem. When a more open-ended program was used, the pupils discussed the best solution and readily proposed (and opposed) ideas and suggested actions. This was demonstrated by the use of a version of the well-known "Animal" program: this, too, will be discussed in detail later (pp 154-160).

CHANGES IN PUPILS' LEARNING

It was shown earlier in this chapter that considerable changes could occur in teaching strategies when CAL was used in the classroom. Such changes in the work of the teacher would seem likely to produce corresponding changes in the work of the pupils: changes would be expected in both the demands made of the pupils and in the pupils' responses to the demands.

An examination of the SCAN records showed that the changes in pupil-activity observed could be regarded as arising from two basic changes in the work-pattern:

> there was a marked increase in the amount of small group work undertaken by the pupils;
>
> the pupils had a greater share in controlling the precise direction and content of the lesson.

These changes were possible where the computer was given the role of task-setter and/or where it where it was used to provide the pupils with feedback on their progress.

The amount of small-group work was, of course, directly in the teacher's control, but the factors controlling the extent to which the pupils made use of their opportunities for discussing and testing ideas are much less easy to define. The more important factors would seem to include the extent to which the pupils:

i) felt secure in the group environment;

ii) were allowed to follow their own ideas;

iii) received encouragement rather than direction from the teacher;

iv) could understand and cope with the demands of the program;

v) had a positive affective response to the setting of the program.

Whilst other factors doubtless play a part in the reaction of the pupils to the computer, the importance of those listed above was revealed by the observations. The importance of these qualitative changes in the learning styles of the pupils will now be illustrated by examining the work patterns which were established in a number of different lessons.

DALCO - Siting Problems in the Chemical Industry

Persuading a group of 25 or so people to take an active part in a discussion is always difficult. The problem is especially acute with pupils around the age of puberty, when they are extremely sensitive to peer-group pressure. However, when a class divides into small groups for discussion the problem appears much less acute: the pupils within each small group will argue and suggest strategies and alternatives quite freely, in a way which is not seen in larger groups.

Because each group is working independently, the number of pupils taking an active part at any one time is much greater and the problem for the teacher becomes one of maintaining contact with all that is going on. It is in this area that the micro can be very beneficial: by providing immediate feedback to the pupils on the consequences of the decisions they have taken, it allows them to test out their ideas and encourages them to speculate on the ideas underlying the particular topic. The following extracts illustrate the extent to which the use of a computer can be a stimulus to pupil-centred discussion. The extracts are taken from the work of Teacher 2, using the DALCO program with a set of fourth-form pupils.

The Lesson

In the latter part of the previous lesson, the teacher had talked about some of the problems involved in siting industry. Copies of the printed Students Notes accompanying DALCO were distributed and some of the problems of manufacturing Aluminium were outlined. Solutions to these problems were not discussed.

When using the program, the first major decision the pupils had to take was to choose which of the three possible sites would be most appropriate for their plant. After the earlier discussion, and having read the Students Notes, the pupils realised that many factors needed to be considered. For example, the available methods of generating the electricity required varied from one site to another: hydro-electric-power at Bamford, coal at Clowne and oil at Whittington, with nuclear power available at any site. Each method had advantages and disadvantages associated with it: while hydro-electric power was the cheapest form of electricity, Bamford was in the Peak District National Park and, in addition to the the problems of obtaining consent for building the plant in a National Park, the level of the Ladybower Dam would have to be raised, flooding more of the Park and necessitating re-routing the A57 'Snake Pass' road.

4	Now where are we going to put it?
2	Er...er... Whittington
T	Why are you going to put it in Whittington?
2	Well, because I don't think you should use Bamford because you know there's scenery and then at Clowne there's a colliery, so the land could be subsided under the colliery - also if you use coal there ...
3	Yes (looks at map)
2	... you're going to have strikes and that, by the miners.
1	At Whittington there's high unemployment ...
T	Yes but ...
1	There isn't any [coal]
3	I know but Clowne's got [coal] ...
1	... and if you built at Whittington, you wouldn't be spoiling any views
T	Alright
3	Clowne's got railway and roads tho' ...
	(all 4 talking at once)
T	You carry on discussing that (leaves group)
2	(Points to map) You could go straight through there ... take off
4	... besides it says not, it says straight through to Immmingham docks anyway.
2	(untranscribable comment)
4	Exactly. 2 - yes. (i.e. select Whittington)
3	2?
4	That's it, come on ... Return ... Space-Bar

(T=Teacher, Number indicates pupil)

Table 4.4

Pupil-Pupil Discussion on Choice of Site

Perhaps the first point to notice in Table 4.4 is that all four of the pupils in the group were actively involved in the discussion. This is by no means unique to this particular episode or class. It was noted whenever a program required a decision where there was no single 'right' answer - and was often recorded where the program did require such an answer.

The teacher input to the discussion was effectively limited to the question on line 3. The importance of this question, from the observer's viewpoint, is that it was typical of the style used by the teacher throughout the session. Within the context of the lesson, the question was classified as 'g3': 'g' because the pupils had to weigh many factors in what, for them, was a 'new' way of working with new material and '3' because it offered no guidance as to the 'right' or 'expected' decision.

The teacher became more directly involved with the discussions of another group working on the same problem (Table 4.5). However, she still avoided giving explicit directions or hinting at a 'preferred' response. Indeed, she was explicit about the absence of any single 'best option' (line 7). From a purely profit-making point of view, 'Bamford' and 'Hydro-Electric Power' would have been the most successful choice as these lead to the lowest running costs for the plant. However, the program and the accompanying worksheets also presented some environmental and social considerations which the teacher felt the pupils should "balance" for themselves.

T	Yes - but why do you say Bamford?
8	(ignoring T's question) Transport's there.
7	Whittington's better - the land's cheap, unemployment as well.
5,6	make inaudible remarks
7	I hadn't even thought about that.
T	(addressing 5 & 6) Why do you say Clowne? I mean, it could be any 3, there's no right answer, so ...
5	Yes but it's ... (untranscribable)
7	(to 8) On the other hand though, Clowne has got a railway line and a motorway.
8	yeah, mmmh
T	Yes, you see Jilly has a suggestion here - that there's a high unemployment in Clowne and there's coal. What was your argument for going to Whittington?
7	Well, the land is cheap and unemployment .. hang-on, where is it? ... Unemployment levels are high, so it would be cheaper to build it.
T	It's cheaper than at Clowne?
7	Yeah - on the other hand though ...
5	... it's cheaper transport ... it's got a railway and motorway near it.
7	So, you reckon Clowne.
T	Yes, so ... go on David, what do you think?
8	I think it's Bamford.
7	Oh (amused) well, you would!
T	Well, put your arguments for Bamford to the board.
8	'Cause there's water, so you can get water and you can only transport the other two.
7	Bamford?
6	Yes, but the roads are short [narrow] though, aren't they?
7	Yeh, in Winter roads are closed, so you'd lose a bit of money there.
T	You've also ...
6	Yes! You'd have to dig up all Snake Pass. You'd have to dig it all up and change that.
5	And then it gets blocked in Winter.
T	Well, have you decided on Whittington? Hang-on (to 6) Whittington or Clowne?
7	It's either Whittington or Clowne, I reckon!
6	Have a vote then.
8	(laughs) or Bamford
7	No! Not Bamford.
6	Have a vote then.
7	Right then! Who votes Clowne?
T	Well, just argue a bit further. You've all agreed to get rid of Bamford. Just go through the arguments again with Whittington and Clowne ... you see you might have a casting vote now because you've rejected Bamford together, so now you've got to decide on the other. (leaves group)

Table 4.5

Choice of Site - No 'Best' Option

As the transcriptions in both tables show, the pupils take little notice, initially, of the relative costs of electricity and are much more concerned about the social and environmental conditions. Only one boy (pupil 8) was sufficiently impressed by the economic considerations to make an initial choice of Bamford, but he did not attempt a defence of his position, as the others defended theirs, until he was prompted to do so by the teacher. This 'prompting' occured very rarely and for most of the lesson the pupils argued freely about the decisions to be taken. They did not, however, use formal hypotheses or conditional statements (IF we do this, THEN that will happen) nor did they formally question each other's suggestions. Instead, as the two tables show, they used a series of assertions and counter-assertions until one side of the argument was abandoned.

Where the teacher used a specific question, the pupils tended to respond in much greater detail than one would expect from observations of non-CAL-based lessons. For example, Pupil 2 responded to the question on line 3 of Table 4.4 by giving a fairly lengthy explanation of the reasons for her choice. This turned into a brief, but heated, discussion by the pupils of the relative merits of Clowne and Whittington, during which two further attempted interjections by the teacher were, effectively, ignored. In a typical 'Whole Class' situation, such a question from the teacher would have met with a much shorter response from a single pupil and the teacher would almost certainly have had to take active measures to involve others in the discussion. Such was the involvement of the pupils in the program that the initial question by the teacher may not even have been a necessary precursor to the discussion.

4 Right. We're having oil.
3 Nuclear!
2 We're not having nuclear.
3 I know, but oil can run out.
4 We're not having ...
2 It can, but nuclear is dangerous.
1 Nuclear is dangerous. Everybody would move away. Nobody would want to live near a nuclear plant and there'd be a lot of demonstration.
3 I know but that's fair because you don't want people round.
1 (untranscribable)
3 Yes, but there's a lot of unemployment in that area, so
1 ... you don't want everybody to move away and everybody's getting ... they're not going to want a nuclear plant building.
2 So, if you've got, you know, demonstrations and that, it's going to waste time.
3 (signals acceptance - smiles - and presses "1" for oil)
4 (makes untranscribable comment about the program's warning regarding use of oil and confirms its choice)

Table 4.6

Pupil-Pupil Discussion on Choice of Power

Certainly, the pupils seemed perfectly willing and able to sustain this sort of discussion without direct teacher involvement. This could be seen as the pupils tackled the next problem - choosing the type of power-station, oil or nuclear - without teacher intervention (see Table 4.6).

The pupils were able to maintain a vigorous discussion throughout the whole of the lesson. A change in the attitudes of the pupils was observed as the results of their decisions were translated into profit and loss for the company. The decision to go for oil, in Table 4.6, quickly became a cause for concern as losses mounted rapidly - finally reaching a figure in excess of #2000 million. The argument amongst this group was between changing the site to Bamford to use H.E.P. and staying at Whittington and trying nuclear power. The latter argument won the day, but the lesson ended before any results from this change could be obtained. It was clear, however, that the pupils had come to regard 'making a profit' as the measure of success. There were two apparent reasons for this:

i) at the end of each annual cycle, the program produced two pages of financial information, whereas the provision of information on evironmental and social considerations was limited to the initial decision-making section of the program;

ii) the teacher often used the financial data produced by the program as the basis for her interjections.

The other group of pupils - 5,6,7 and 8 - had chosen a coal-fired power station and, as their initial debt was reduced, they moved into an operating profit. They still showed concern about their choice of fuel, however, on seeing the proportion of the costs which were tied to the production of electricity.

Table 4.7 shows that the pupils felt able to explain their (earlier) discussions of the need for change to the teacher. In line 5, one of the pupils makes use of the program itself to demonstrate the basis of their arguments by pointing to a selection of data on the screen. This represents a further indication of the way in which pupils can feel secure in their work with a computer and can use this security to make real progress.

T	What do you think about your original decisions in the light of your results now?
7	Well, rail was good.
6	Transport's good.
7	Yes because look. [Selects summary of costs.]
T	If you could change your decisions, would you change any of them, I wonder?
6	Mmmh.
8	I'd change electricity.
7	Yes, it's getting a bit high.
5	You don't know what the other ones would be like - they might be worse.
T	Yes [reflectively]
8	No harm in trying them.

Table 4.7

Seeking Improvements

As with the DALCO example in the secondary school, primary school teachers were also found to be using open-ended programs in a pupil-centred environment. Here, too, small-group, pupil-centred work was found to stimulate on-task, pupil-pupil discussion and the micro was found to provide good stimulus and support for such work.

ANIMAL - a Classification Program

Teacher 10 had done some work on 'classification' with her 'M4' class (12 year-old Middle School pupils) and had decided to use 'ANIMAL', a program with which she was familiar, for group-work on the topic. "ANIMAL", written by the father of a child at the school, was an open-ended, content-free program based on a binary-tree system of classification. It had been written for the school's two Sharp MZ80K micro's and had been in use in the school for two years.

Two groups of four pupils were each given a (different) list of several kinds of animals. They were expected to use reference books to look up facts about the animals and to use these facts to generate a series of questions which would enable them to distinguish one animal from another. The list of animals was not taken as prescriptive and the pupils were free to add animals to the list (or to omit them). The two groups worked independently: each group had its own micro, but they shared access to a large number of reference books.

The pupils' task, in effect, was to "teach" the computer to recognise the different animals. To do this, the questions generated had to be such that the branches of the tree led, eventually, to a specific animal. When the key was complete, the other group of pupils would "test" the computer by picking an animal from the list and answering the questions asked by the computer. In this way, the key itself would be critically assessed (for example, "that's a stupid question") by the pupils and the pupils in each group would receive feedback about the quality of their work. The teacher hoped that this would give the pupils some insight into the workings of simple classifications and into the methods by which they can be constructed.

The Lesson

Like DALCO, the lesson was notable in that, after the introduction, it consisted largely of pupil-pupil dialogue with the teacher intervening occasionally to assess the progress of the groups and to give direction where the pupils were having problems agreeing on suitable questions. There was no attempt to prescribe the type of classification used. Indeed, given the background and age of the pupils, it would have been inappropriate to attempt to force the use or development of a formal, "scientific" classification. A sample of the computer dialogue, taken from part-way through the session, is given in Table 4.8.

```
ARE YOU THINKING OF AN ANIMAL? Y

DOES IT SWIM? N
DOES IT DIG? N
DOES IT CARRY ITS YOUNG IN A POUCH?  N
IS IT BLIND? N
IS IT A BIRD? N

THE ANIMAL YOU WERE THINKING OF
WAS A ? LEMUR


TYPE IN A QUESTION THAT WOULD
DISTINGUISH A LEMUR FROM A BIRD.

? IS IT A PRIMATE

FOR A LEMUR THE ANSWER WOULD BE ? Y


ARE YOU THIKING OF AN ANIMAL? Y

DOES IT SWIM? N
DOES IT DIG? N

etc.
```

All input and output was in upper case.
The user responses are shown underlined.

Table 4.8

Sample Computer Dialogue.

Apart from the question in line 1 - "ARE YOU THINKING OF AN ANIMAL?" - all the questions were devised and entered by the pupils during the course of the lesson. The next five questions are those entered by the pupils to identify their chosen animals, ending with "IS IT A BIRD?". As the answer is "NO", the computer recognises that this is a "new" animal and asks for its name - lines 7 & 8 - and for a distinguishing question - lines 9 & 10. Once these have been answered correctly the process is repeated.

As with DALCO, the SCAN of this lesson shows a relatively low number of 'explanation' and 'instruction/initiation' events and a marked preponderance of pupil-initiated checking-questions and assertions (see Table 4.9). Once again, the great majority of the assertions are simple statements of fact or supposed fact. Simply looking at the numbers of these events tends to disguise the true nature of the work in this lesson: an examination of the SCAN shows that the pupils are using sequences of such assertions to move toward the solving of a problem or the synthesis of a "new" idea. This again agrees with observations in other lessons, where children showed a tendency to avoid asking formal 'questions associated with content'. Instead they made assertions of 'fact' which the other pupils then confirmed or rejected. The 'rejection' itself sometimes simply took the form of a counter-assertion or an alternative suggestion.

	Remark Level														
	Associated with Content										Social, Organisational, Procedural				
	q	a	e	i	k	r	s	x	cc	cf	ch	g	m	v	p
t	27	10	1	1	2	1	3	0	0	7	27	0	6	0	1
p	0	130	4	2	3	6	38	2	0	7	79	0	0	0	4
tot	27	140	5	3	5	7	41	2	0	14	106	0	6	0	5

Key: t = teacher initiated p = pupil initiated
tot = total number of events

Table 4.9

Other Events

While the SCAN cannot formally show 'enthusiasm' or 'motivation', this is, perhaps, indicated to some extent by the sheer number of pupil-initiated events in this 30-minute session. The positive affective responses of pupils to this program and to others, for example DALCO and CONTACT, is very evident in the classroom where the pupils need little or no encouragement to tackle the problems presented and to suggest ways in which difficulties may be overcome.

Where the teacher broke into the pupil-pupil dialogue, she often made use of a question-and-answer technique to monitor and control the pupils' progress. As Table 4.10 shows, the questions used were often open-ended and required a considerable amount of 'original' thought by the pupils.

<------ Depth of Demand ------>

LEVEL OF GUIDANCE	/ ' x o	α	β	γ
	1	7 1 1 1	2 0 0 1	0 0 0 0
	2	0 0 0 0	2 1 0 0	1 0 0 0
	3	0 0 0 0	1 3 0 2	2 1 0 1

Key to responses: / '
 x o

/ = correct ' = partly correct
x = wrong o = no response

Table 4.10

Teacher Initiated Questions and Pupil Responses

The following extract (Table 4.11) illustrates a typical teacher intervention to give direction: the pupils had spent some time discussing ways of distinguishing a fish from a whale before the teacher interrupted.

T	What question have you got?
4	Miss, "Is it big?"
T	What's a better question, what's the difference between a whale and a fish?
3	"Has it got a hole in its head?"
T	Even a bigger difference than that....
T	What sort of animal is a whale?
4	A mammal
T	What sort of animal is a fish?
3	I've forgotten.
4	...it's a mammal isn't it?
3	No it isn't it lays eggs
T	Is a fish a mammal?
3	No
2	A fish belongs to its own family
4	Is it in its own group, a fish?
T	Yes it's in its own group, so there's a group, "fish".
4	"Is it a mammal?"
T	That's right!

Table 4.11

Extract from the Transcript.

In lines 3 and 4, the teacher reiterates the basic question the pupils have been trying to solve. In line 6 she rejects the pupil's response and effectively puts the question again. When the pupils do not respond, she re-phrases the question to provide slightly more guidance (line 7). This produces an immediate, correct response from Pupil 4. This technique of increasing the guidance when pupils do not respond was observed in all the teachers participating in this study and, as here, it often proved successful in stimulating a pupil-response. This was, in fact, the critical question in this exchange:

after this, the response time of the pupils decreased markedly and the teacher's questions appeared to be almost a formality. It should, perhaps, be pointed out that in, line 19, the pupil is making a suggestion of an appropriate question to distinguish a whale from a fish!

Summary

An important point regarding the pupils' work was that the micro did not provide a knowledge-base, nor were the pupils required to work solely with facts they already knew about the animals. Every encouragement was given to the pupils to look-up data in the reference books provided and to co-operate in the selection of what seemed most appropriate. (This, in itself, could be seen as a valuable learning activity which is missed in many formal - and informal - classroom situations.) This integration of the micro with other classroom resources was a regular feature of much of the good practice observed in this study.

Teacher-Control and Pupil-Learning

It was clear throughout the previous discussion that the pupils were able to follow their own ideas. This was not always so, even with programs intended to promote pupil-centred discussion. The two lessons to be discussed in this section illustrate the effect of close teacher-direction on pupils' learning styles.

A Teacher-Led Discussion

FERTILIZER was written by Teacher 6 as an aid to teaching this (then) newly-introduced topic to fourth-year 'O'-level chemistry classes. The program was menu-driven and allowed the user to select a crop and a soil type and to define an N-P-K mix for the fertilizer. Simple pictorial representations of the growth of the crop - roots, leaves and seeds, as appropriate - were used to indicate the effect of the fertilizer and scores were given as a percentage of the ideal mix for that particular crop/soil combination. The program then gave individual scores for the N, P and K elements, allowing the user to change any of the conditions before repeating the growing cycle.

An examination of the SCAN record shows that the lesson began with a short revision episode, covering the previous day's work and, thereafter, followed a classical teacher-exposition pattern: all events being under the close direction of the teacher. This 'close direction' is clearly illustrated by the following events which began the 'new' work for the day.

T. ..... And what we are going to try to do
this afternoon is see what particular
elements are needed for what particular
crops. And we'll do this by actually
trying to grow a particular crop and seeing
what happens and this is where the computer
will help us. So we've got a list there of
several different crops that a farmer might
want to grow. Now we don't know much about
where to start yet or what to do.
So should we think of a crop, something
that maybe you'ld like to eat?
P. Carrots
T. Carrots, you'd like carrots ....
Shall we try strawberries to start with?
We'll try strawberries - we'll come back to
carrots later on. So we've chosen
strawberries, which is letter ...... ?
All "G"

Table 4.12

Teacher Control of Ideas

The passage illustrates a very common teaching tactic: the teacher apparently wants the pupils to choose the examples (and hence the route through the lesson) but only if, in doing so, they conform to his predetermined lesson pattern. In this case, the initial question (line 11) appears to suggest an open-ended approach to the lesson, while his response (line 15) to the pupil's selection of "carrots" shows that he had a clear view of how the lesson should proceed and was not going to allow any other routes at this stage. How far he was consciously aware of this is not certain: he says "we've chosen strawberries". This pattern of close teacher-direction of the lesson was to remain in force until the last few moments of the tape, when he started to allow the pupils to make the decisions: by this stage, however, he had clearly covered his intended teaching-points.

An examination of the details of the SCAN record clearly illustrates the close direction, teacher-domination which prevailed in the lesson. The teacher alone asked questions of content, gave instructions and explanations and initiated new activities. As might be expected, he also made significantly more assertions than the pupils. The role of the pupils in this lesson was obviously a very passive one, in which all knowledge and direction came from the teacher and his "assistant", the micro. The extent of teacher control of the lesson structure is illustrated in Table 4.13.

	<---- Remark Level ---->														
	Associated with Content										Social, Organisational, Procedural				
	q	a	e	i	k	r	s	x	cc	cf	ch	g	m	v	p
t	43	76	10	11	5	4	4	2	0	27	48	5	39	0	2
p	0	34	0	0	4	1	52	0	0	0	10	0	0	0	0
tot	43	110	10	11	9	5	56	2	0	27	58	5	39	0	2

Key: t = teacher initiated
p = pupil initiated
tot = total

Table 4.13

Events Recorded

An examination of the table clearly shows the passive, receptive role of the pupils in this lesson: the pupils made no contribution to initiating events in the lesson nor any attempt to explain those events. Even the interpretation of the information presented by the program, was largely controlled by the teacher, any apparent pupil explanations taking the form of an answer to the teacher's questions. Questions from the teacher provided the foundation on which this lesson was built; direct answers and supplementary assertions and suggestions formed the main pupil activity. This restriction of pupil-initiated events to 'suggestion' and 'assertion' seems to be a common characteristic of, though not exclusive to, teacher-led lessons. Table 4.13 also shows that the teacher made a large number of managerial statements and that he was constantly checking on the progress made by the pupils. This combination of restricted pupil activity and close direction by the teacher is also characteristic of a teacher-manager role.

The two extracts from the transcript, shown in Table 4.14, are typical of the way in which the teacher used the question-and-answer technique to control the examples used by the pupils. In the opening lines of Extract 1, the pupils were asked to choose an NPK value for the fertilizer (line 7) and a pupil promptly offered what was, in principle, a perfectly acceptable value (line 8). The teacher, however, had clearly decided that a different entry point was desirable and the initial suggestion was rejected. A second pupil suggestion was also rejected in favour of the teacher's own ideas (line 15). While the teacher may have had good cause to start his search with a median value, such reasons are not made explicit (line 18) and the pupils could be forgiven for thinking that their suggestions were "just as good".

Extract 1

T. ..... Now we can choose the amount of nitrogen, the amount of phosphorus and the amount of potassium. Right. We can choose percentages and the only condition is we mustn't go above 25%. Right. We can have up to 25% of each. Now we've no idea at the moment have we? So, think of some numbers.

P1 Three 17's.

T. You think three 17's. Why all the same?

P1 'Cause it's on there. (a leaflet showing fertilizer bags)

T. Well there happens to be one there that's 17-17-17

P2 (inaudible comment from back row)

T. You say 10. ... Well 12. Why 12?

P2 'cause that's there as well. (on the leaflet)

T. Oh! Alright. Well 12 is half, half way up - you know - half way between 0 and 25. And if we choose the same for each, 12, 12 and 12, let's see what happens. So if I type in 12, 12, 12, and let's see what happens. ......

Extract 2

(After commenting on the results obtained in "Extract 1", the teacher is reading from a menu on the screen)

T. Well we can do any one of those things. We can change all the values, or change one of them. Or we could change the soil type, change the crop, see the best answer .. or get some hints.
What do you reckon should be the best thing we should do?

P3 Change the soil.)

P1 Change the nitrogen value)

T. We could change the Nitrogen value .. yes. Would we make it higher or lower?

P1 I'd make it higher.

T. You think it would be higher? Why do you think it would be higher?
(boys laugh - signifying no reason)
Well it might be higher, but .. er .. anything better than that? You know .. er .. we're in the dark still aren't we. We only got 57%.

P1 Why don't you ask for some hints then. Ask for some hints.

T. Well maybe let's try a hint. See what the hints are like, so that's ... "G" (from the menu)

Table 4.14

Two Extracts from the Transcript

In Extract 2 we see the same principle at work, though perhaps less obviously so. At first, the teacher seemed to be taking up the suggestion of Pupil 1 (line 10) but, by suggesting that they were still "in the dark" (line 17), he was able to manoeuvre another pupil into suggesting that they try "Hints" from the menu (line 18). This suggestion was immediately accepted by the teacher!

The 'encouragement' given by the teacher in the 'DALCO' lesson was largely absent in the early parts of the 'FERTILIZER' lesson. It was only in the last third of the lesson that the teacher felt able to allow the pupils more freedom in their choices, saying:

> "Right. Well I think you've got the idea now. I'll throw it a bit more over to you. You can choose any crop you like."

Even here the freedom was limited, for as soon as the crop had been chosen he went on to say:

> " ... We'll do a couple of these and then, if we've got time, we'll have a look at soil types."

The declared aim of the author of FERTILIZER was to let the pupils "develop a feel for what fertilizer to use". He was not concerned with teaching specific values of fertilizer mixtures for specific applications. He was concerned that the pupils should understand, for example, that a seed or fruit crop would need a high potassium fertilizer. Teacher 6, nevertheless, approached the problem in much the same manner as he approached more traditional 'theoretical' aspects of the syllabus and, in so doing, he minimised pupil-control in the lesson and denied himself much of the feedback which a true discussion would have provided.

The Electronic Blackboard Approach

Where a program was intended, by the teacher, to deal with a specific content area, the amount of freedom allowed the pupils was, as might have been expected, even more restricted than in the FERTILIZER lesson. The work of Teacher 9, using the 'Lens Calculations' program mentioned earlier, provided an example of this tighter teacher control.

The program, LENS, used in this session was written by the teacher and was intended to help the pupils with the simple-lens calculations found in many 'O'-level physics syllabuses. Using the formula:

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

where: f = focal length,
u = distance of object
v = distance of image

the computer is used to draw "ray diagrams", print the values of "f", "u" and "v", and to state the type of image formed. In practice, the user had to supply two of the three values and the computer calculated the third.

The pupils were from the fourth-year "physics 'O'-level set 2". They had already done various standard laboratory experiments using ray-boxes with lenses, mirrors, glass blocks etc. The teacher had designed the program as an aid to consolidating the topic and as a means of encouraging the pupils to work through the sorts of problems commonly encountered at 'O'-level. The syllabus required the pupils to solve the problems graphically (rather than by using the formula) and so the formula was not explicitly presented; the ray diagram and image description given by the computer was intended to provide the pupils with a means of checking their own work and of examining where any differences had arisen.

Given this basic design premise, it is scarcely surprising that the pattern revealed by the SCAN showed a fairly typical structure for a revision-based lesson. The demands made on the pupils were confined mainly to factual recall, with only a limited synthesis of ideas expected and no breaking into new ground.

	<—— Remark Level ——>														
	Associated with Content										Social, Organisational, Procedural				
	q	a	e	i	k	r	s	x	cc	cf	ch	g	m	v	p
t	28	39	21	20	0	0	6	7	0	24	20	5	14	0	9
p	0	2	0	0	0	0	5	0	0	0	1	0	0	0	0
tot	28	41	21	20	0	0	11	7	0	24	21	5	14	0	9

Table 4.15

Events in the 'LENS' Lesson

Also very evident from the SCAN, was the extent to which the lesson was teacher-led. The pupils had very little opportunity to make independent contributions to the lesson, still less to control the rate or direction of its progress. Even assertions were scarcely used by pupils in this lesson, in stark contrast to the observations in 'DALCO' or 'ANIMAL'. Table 4.15 shows the extent to which teacher-talk dominated all areas of the lesson.

The lesson alternated between 'Ew' and 'Wl' activities. The 'Ew' activities were principally used to set the scene for the individual work to follow. In them, the teacher used a question-and-answer technique to elicit, from the pupils, the form of the ray diagram and the type of image produced for given examples: at each stage he used the micro to show the values used, the corresponding ray-diagram and the type of image formed. The pupils were then given a number of similar situations and asked to produced scaled ray-diagrams on graph paper.

The pupils worked individually at producing these diagrams and all the 'Wl' activities were characterised by periods of silence, with no pupil-pupil interaction and only minimal intervention from the teacher. The activity ended when the teacher judged that most pupils had finished the diagrams and the lesson returned to an 'Ew' activity. The figures used in the problems were entered into the micro, by the teacher, and the resulting displays were compared to those produced by the pupils.

This cycle of giving examples on the micro, working on pencil-and-paper problems and then checking the results on the micro, was repeated, with virtually no pupil-led events, until the end of the lesson. The use of the micro as an 'electronic blackboard' allowed the teacher to produce clear, scaled diagrams much more easily than would have been the case with a conventional chalk-board.

Certainly, the teacher felt that he covered more examples than he could otherwise have done and that, therefore, he was able to use examples chosen by the pupils more readily than if a micro had not been available.

From an observer's viewpoint, however, the examples appeared to be chosen under careful teacher guidance:

> " ... what would happen if the object was
> close to the lens?
> Choose a distance less than the focal length ...."

It seems probable that very similar examples would have been used had the teacher openly chosen the distance himself and that here, as in other parts of the lesson, real pupil-control of events was minimal. It seems equally probable that the pupils would have used many examples covering the effects the teacher wished to demonstrate had they had control of the micro themselves and that the lesson might have taken on a different character had this been the case.

The Importance of the Knowledge-Base

The ability of the pupils to understand and cope with the demands of the program is an obvious pre-requisite for its successful use in the classroom. The pupils appeared to benefit from the use of the computer in a variety of settings, as can be seen, for example, in DALCO, CONTACT and DECOMP. Their positive response to the programs was possible because they understood what was expected of them and had access to an appropriate knowledge-base on which to build. The effect of failing to meet these conditions was illustrated in the work of Teacher 7 with an upper-sixth 'A'-level chemistry set.

The Element Game

ELEMENT was intended for pupils following an 'A'-level chemistry course. The program presented an "unknown" element which the students had to identify, using a series of tests. The program provided a simple scoring system which deducted a number of points, from the initial 200, for each test used. The students were expected to identify the element for the least "cost".

The original version of the program was implemented on a mainframe computer for use with remote teletype terminals: it was later adapted for use on the early microcomputers. At the time of these observations, the program was again being re-written to make use of the more advanced facilities and programming techniques which had become available. The changes to the program were considerable, both in terms of screen design and the mode of interaction with the user. The basic model used by the program was, however, unchanged: a trials version of the new program format was used for this session.

The pupils involved had gained some knowledge and experience of the procedures used in identifying the elements in inorganic compounds, in both theory and practical lessons. They were also familiar with the meanings of all the terms used in the students' worksheets (first ionisation energy, hydrated ions etc).

The lesson opened with a brief introduction in which the teacher outlined the procedure to be followed, with the pupils then working in two groups of four. The teacher explicitly introduced a competitive element in which the two groups had to keep a running total of their scores, the winner being the group with the greatest total score. The lesson then proceeded almost entirely in pupil-pupil dialogue, with interjections from the teacher taking the form of assertions and suggestions with a few, fairly simple, questions.

The SCAN of this lesson had many similarities to those of other pupil-centred lessons, such as ANIMAL or DALCO. In particular, there was little formal use of questions by either teacher or pupils and there were relatively few initiation/instruction events. Once again, the pupils worked outside these formal linguistic structures and, instead, used assertions, suggestions and checking questions to approach the desired end. (See Table 4.16)

	Remark Level														
	Associated with Content										Social, Organisational, Procedural				
	q	a	e	i	k	r	s	x	cc	cf	ch	g	m	v	p
t	15	25	6	11	2	2	7	1	0	5	15	0	3	0	0
p	3	144	1	2	7	4	55	0	0	7	57	0	0	0	0
tot	18	169	7	13	9	6	62	1	0	12	72	0	3	0	0

Table 4.16

Events in The Element Game

This pattern began to be revealed immediately after the teacher had completed his initial "exposition". The following SCAN extract records the opening pupil-pupil dialogue: the prefix to each event shows the 'speaker': t=teacher, c=computer and a number indicates a pupil.

tiα1	8aα1	7s	8ch	ciα1	taα1
7s	8ch	7eβ2	8r	6s	7s
8ch	7aα1	caα1	8aα1	//AR	

The events on the first line were concerned with 'getting started'. The computer presented the first 'unknown' element, "An Invisible Gas", and the teacher made a simple assertion "You've got an invisible gas and your start score is 200". The pupils then argued whether to test 'solubility' or 'burning'. On the third line, Pupil 8 checked that all the group were happy with the test chosen and Pupil 7 read out the test as she made the selection. Pupil 8 then read out the computer's response.

The way in which the pupils responded to the problems posed by the program suggested that they were not used to applying their knowledge in problem-solving activities. This was especially evident in the early stages of the session where they made many guesses, despite the heavy penalties (in points) for being wrong. During the course of the lesson, the effect of this on their scores began to have an effect on their approach to the problems: where they had sufficient knowledge, they made increasing use of the information and tests available.

In both DALCO and ANIMAL, the pupils were provided with reference material which supplied the knowledge-base by which they could make their decisions. This allowed the pupils to discuss which information was most important and how it should be applied. In contrast, the teacher in ELEMENT had not provided any reference materials for the pupils, even though a complete set of 'test results' was available in the Teachers Notes for the program. This would not have mattered, of course, had the pupils had a thorough knowledge of the subject area. However, their knowledge of some quite elementary chemistry seemed less than perfect and choosing a suitable test and interpreting its results caused problems throughout the session.

The pupils' use of the 'Flame Test' provides an example of the effect of this lack of a knowledge-base. This is an important test, both in the school laboratory and in the program - in fact it will positively identify almost half of the metals in the program. Neither group of pupils used this test systematically and both demonstrated a lack of basic knowledge about which metals have a visible effect on the colour of a flame. This often left the pupils with little option but to guess at the name of the element.

The program was seen, by its authors and by the teachers who used it, as helping pupils to absorb facts about the properties of the elements and to organise these facts so that they could be used to identify the elements. It was not intended as an initial teaching package and could not be used to present information about any given element. While one might have expected an 'Upper-Sixth' class to have been familiar with much of the information needed, the overwhelming impression gained was that the basic facts were not known, nor were they available. Such a lack of information was inevitably frustrating for the pupils and led to the loss of much of the program's potential value.

During the observations reported in this study, it became apparent that a given teacher-class combination adopted differing strategies for differing styles of program. Some programs appeared to encourage an open-ended, pupil-centred approach, whilst others were used with a much greater degree of teacher-control of the learning situation. This difference was clearly illustrated in the work of Teacher 2 using DALCO and FORMULA with a group of fourth-year 'O'-level pupils. DALCO has been described earlier (pages 146-154).

FORMULA was intended to help 'O'-level and CSE students to learn how to construct simple formulae for inorganic compounds. The program allowed 'easy' or 'harder' examples to be selected and then presented an apparently random selection of five items from a list of elements and radicles. The pupils then had to choose two items from those presented and work out how many of each would be needed to give a correct formula. To help this process, the teacher had provided a worksheet showing the 'valencies' or 'combining powers' of the species met in the program. If two items were chosen for which there was no corresponding compound, then the computer asked the user to choose again. The program used a simple scoring system, adding 20 for each correct attempt and subtracting 10 for each error. Chemical symbols and formulae were displayed in large type with true sub and superscripts. There was no set number of attempts and the user could change the list of elements or the level of play at will.

The Lessons

The two sessions, using DALCO and FORMULA, illustrated two very different lesson structures: the teacher's use of DALCO provided a strongly pupil-centred, open-ended session, while her use of FORMULA came much nearer to the traditional teacher-based, expository approach. This difference can be clearly illustrated by comparing the SCANs of the two sessions.

At the broadest level, the SCANs showed differences in the types of activities which arose in the lessons. The DALCO session began with a single, whole-class exposition in which the teacher introduced the work: for the rest of the lesson the pupils worked in groups of four, discussing the problems which arose, with little intervention from the teacher. FORMULA, however, gave rise to a completely different pattern in which teacher exposition to the whole class alternated with the pupils working individually on a single problem. In this respect, the FORMULA session appears to have been very like a traditional "theory" lesson.

Differences were also apparent at the episode level. In DALCO, the episodes were largely based on conversation or argument between pupils, in which they vocalised their ideas and used the computer-generated data to predict the conditions for success. This was in marked contrast to FORMULA, in which the search for "correct" answers was effectively controlled by the teacher: there was little opportunity for the pupils to discuss their ideas, almost all 'talk' occurring between teacher and pupil.

Even at the most detailed level of observation, the event level, there were clear differences between the two sessions. This can be illustrated by comparing the types of events which occurred in each session.

DALCO: ←----- Depth of Demand -----→   FORMULA: ←----- Depth of Demand -----→

LEVEL OF GUIDANCE	DALCO / ' x o	DALCO α		DALCO β		DALCO γ		FORMULA / ' x o	FORMULA α		FORMULA β		FORMULA γ	
1	1	3	0	3	0	0	0	1	9	1	14	0	0	0
		0	1	0	1	0	0		1	0	0	0	0	0
2	2	0	0	2	0	0	0	2	2	1	4	1	0	0
		0	0	0	3	0	0		0	0	1	2	0	0
3	3	0	0	3	0	2	1	3	0	0	2	1	0	0
		0	0	0	0	0	3		0	0	0	0	0	0

Key to Responses | / ' x o | / = correct   ' = partly correct   x = wrong   o = no response

Table 4.17

Teacher Initiated Questions and Pupil Responses

$x^2 = 7.30 \qquad p < .01$

An examination of the question-style used by the teacher reveals distinct differences between the two sessions. Table 4.17 shows that the teacher's questions in DALCO were significantly more demanding and more open-ended than those used in FORMULA. As was commonly found in this study, the pupils made little or no use of questions in either session and, instead, used a combination of assertions, suggestions and checking questions in their search for solutions.

LEVEL OF GUIDANCE	DALCO ←----- Depth of Demand -----→						FORMULA ←----- Depth of Demand -----→					
t p	α		β		γ		α		β		γ	
1	18	146	3	19	0	0	17	6	3	0	0	0
2	0	1	3	29	1	1	0	0	0	0	0	0
3	0	0	0	9	0	9	0	0	0	0	0	0

Key |t p| t = teacher initiated p = pupil initiated

Table 4.18

Assertions

$X^2 = 73.47 \quad p < .001$

The sheer number of pupil-assertions in DALCO makes it obvious that the pupils were highly involved in what was happening in the lesson (see Table 4.18). The small number in the FORMULA session, however, need not necessarily imply a lack of involvement: the involvement could have been non-verbal and, therefore, not formally recorded in the SCAN. However, this apparent lack of involvement does pose one of the classic problems for teachers: 'Do they understand what I am saying?' Without the kind of feedback which was present so abundantly in DALCO, the teacher has to rely on non-verbal cues, such as facial expression and body posture, and an opportunity to 'overhear' the children thinking is missed.

The differences in teacher and pupil roles was also demonstrated by the use the teacher and pupils made of explanations in the two sessions. Table 4.19 shows that, in DALCO, the pupils were explaining (to each other) the events of the lesson, whereas in FORMULA the explanations were coming from the teacher. Here again, DALCO can be seen as having provided an opportunity for the teacher to gain insights into how the pupils were thinking.

DALCO

←----- Depth of Demand ----→

LEVEL OF GUIDANCE	α t	α p	β t	β p	γ t	γ p
1	0	3	1	5	0	0
2	0	0	1	15	0	1
3	0	0	0	1	0	1

FORMULA

←----- Depth of Demand ----→

LEVEL OF GUIDANCE	α t	α p	β t	β p	γ t	γ p
1	6	0	4	0	0	0
2	0	0	3	0	4	0
3	0	0	2	0	0	0

Key |t p| t = teacher initiated p = pupil initiated

Table 4.19

Explanations

$x^2 = 40.43 \quad p < .001$

On the initiation/instruction spectrum too, a marked difference was found between the two sessions (see Table 4.20). In DALCO these were little used after the opening exposition; in FORMULA there was a constant stream of such events, mainly simple instructions, throughout the lesson, demonstrating the extent to which the teacher was directly involved in managing the learning situation.

LEVEL OF GUIDANCE	DALCO α t	DALCO α p	DALCO β t	DALCO β p	DALCO γ t	DALCO γ p	FORMULA α t	FORMULA α p	FORMULA β t	FORMULA β p	FORMULA γ t	FORMULA γ p
1	3	2	1	0	0	0	28	0	2	0	0	0
2	0	0	1	2	0	0	0	0	2	0	1	0
3	0	0	1	1	2	0	0	0	3	0	0	0

(Depth of Demand: α, β, γ)

Key |t p| t = teacher initiated
p = pupil initiated

Table 4.20

Instruction/Initiation

Fisher Exact Probability (combined scores) = 6.7×10^{-4}

Table 4.21 shows that these differences persisted throughout the whole range of events. In fact, the pupil-suggestions and examples in FORMULA were made after specific requests by the teacher, for example "Julie, choose the first symbol."

The similarity of FORMULA to the traditional 'theory' lesson was apparent at all levels. It was only in the last few moments of the session that the teacher began to let the pupils work on their own with the micro. The pupils reacted to this use of the program in much the same way as to a book-based exercise, working the problem out in isolation with no pupil-pupil discussion.

		Remark Level: Associated with Content						Remark Level: Social, Organisational, Procedural				
		k	r	s	x	cc	cf	ch	g	m	v	p
DALCO	t	2	1	10	2	0	9	28	10	2	0	0
DALCO	p	13	8	47	2	0	40	32	2	0	3	0
DALCO	tot	15	9	57	4	0	49	60	12	2	3	0
FORMULA	t	3	1	0	9	0	27	20	8	34	0	9
FORMULA	p	2	0	6	12	0	0	1	0	0	0	0
FORMULA	tot	5	1	6	21	0	27	21	8	34	0	9

Key: t=teacher p=pupil tot=total

Table 4.21

Other Events

$X^2 = 92.58$ $p < .001$ $X^2 = 92.58$

In contrast, DALCO was driven by discussion. Table 4.22 shows a section of the transcript in which a group of four pupils were examining the accounts of DALCO for the last year's trading and were trying to decide how many kilotonnes of Aluminium should be produced "next year".

From the first assertion (line 1) about the level of the stock of Aluminium, the pupils moved swiftly to examine the reasons for the changes in costings and their increasing losses. The discussion showed that the pupils had correctly identified (lines 4,7,10 and 11) two of the principal cost areas - electricity and loan repayments - and that they were able to relate these to other factors, such as annual production (line 14) and stock carried (line 16). During the session, they were, in fact, able to deal with quite complex ideas by a series of simple assertions, counter-assertions and suggestions. They did not use conventionally structured questions, nor (at this stage) did they formalise hypotheses.

1	We've already got 50 in stock.
4	Do you want summary of costs?
3	No ... we know that already.
4	We don't because electricity might have gone up.
3	Alright ... go on then.
1	That's dropped back down to - repayment - back to 85 from what it was.
3	Has electricity dropped?
2	It's gone up.
4	It's gone up just a little bit ... but that's dropped (pointing) and that's gone up.
3	Not much and yet we did [make] 250 [kT] ...and yet it's not gone up that much.
2	Yes, but we had 50 in stock.

Table 4.22

Extract from the Transcript of DALCO

They did, however, investigate the sorts of factors which might, in other circumstances, have been explored by the teacher in a question-and-answer session. Equally, they tested out various hypotheses (which were often only partly vocalised by any individual) and they arrived at reasonable conclusions. Indeed, by the end of the thirty-minute session, this particular group had realised that their problems arose principally from their choice of oil as a fuel and they had begun to discuss alternative strategies such as changing the fuel and/or using a different site.

The passage quoted was typical of the whole lesson in that there was little or, in this case, no teacher intervention. The pupils felt free to pursue their own lines of reasoning and the teacher took on a role which was perceived as much less directive than that normally found in the classroom.

Summary

Such differences in the teacher's approach were by no means limited to this particular teacher/class combination nor to these particular programs. Programs such as ECELLS, SYNTH and FORMULA were designed to be used in teaching particular content areas of the chemistry syllabus and the use of such programs was always found to be largely under teacher control. On the other hand, programs such as DALCO, CONTACT and DECOMP were often seen, by the same teachers, as useful in transmitting concepts or ideas in a highly pupil-centred setting.

It is tempting, therefore, to relate the differences in setting to differences in the program styles, especially when, in the DALCO/FORMULA case, many other factors (the teacher, the pupils and the physical setting) remained unchanged. It is possible, however, that the differences in approach are due in part to the differences in the nature of the topics themselves. It may be that content-centred topics engender teacher-centred approaches and that topics which are more open-ended encourage pupil-centred approaches. However, it is difficult to see how topics such as DALCO and the CONTACT process could be tackled in a quantitative manner without using a micro. Indeed, observations of the teaching of the Contact process **without** a micro typically show a fairly short teacher-led 'discussion' followed by a statement of the 'industrial conditions'.

Perhaps there is a more fundamental factor in program style than, say, screen design or how the program is driven (important as these are). Programs concerned with **process** - with 'how' and 'why' - seem to encourage teachers to take a pupil-centred approach, even where the topic would normally be dealt with in a traditional, teacher-centred manner. More recent programs, such as BONDING and PERIODICITY, have attempted to encourage this pupil-centred approach in the teaching of what are often considered to be 'content' areas of the syllabus. By using the micro's ability to handle large amounts of data, the development of more open-ended, exploratory learning situations in traditional content areas seems possible. While early reports (Spring 1986) of the use of such programs seem encouraging, time constraints prevent a full analysis here.

Chapter Five

The Interpretation of the Observations

INTRODUCTION

The observations reported in the last chapter revealed the differences which can arise in the classroom practices of both teachers and pupils when a computer is used in a lesson. In this chapter, these differences will be drawn together to illuminate the main areas of change and a rationale will be discussed which shows how these changes arise and the implications they have for the classroom teacher and the program designer. As in Chapter 4, the principal changes will be discussed in terms of the strategies and tactics used in teaching and learning: strategic changes are those which affect the way in which the teacher and/or the class approaches a major part of a lesson or a series of lessons; tactical changes are those which affect the interactions of the individuals concerned within a specific episode or series of episodes in a lesson. For example, a teacher may decide to tackle a topic in an investigatory manner with a group-work approach rather than by exposition to the whole class: such a decision would mark a strategic change. A tactical change could be said to have occurred where a qualitative difference was found between pupil-pupil or pupil-teacher interactions in the events of the lessons being compared. Tactical changes would include, for example, questions being phrased in a more open-ended and/or a more demanding manner, an increase in on-task pupil-pupil discussion or a

Such changes are not trivial: they can have profound and far-reaching consequences for the nature of classroom activities of a kind that are widely regarded as essential for pupil progress. Indeed, major educational reports (Cockroft, 1982 and Bullock, 1975) have highlighted the need for a move away from teacher-exposition to a more child-centred, investigatory approach to teaching and learning.

The observed changes in strategies and tactics were often associated with changes in the control of the knowledge-base of the topic. In most classroom situations, it is the teacher who controls the pupils' access to the knowledge-base and the feedback they receive regarding it. Profound changes in classroom activities have been noted wherever the use of CAL has been associated with a change in the control of the knowledge-base. In ceding control of the knowledge-base, the teacher changes the power-structure within the classroom and opens the way to active pupil-participation in the lesson. In the observations, the use of a micro was found to facilitate pupil-control of the knowledge-base, especially where it was associated with small-group management structures and an open-ended, investigative approach. In such circumstances, high levels of pupil-involvement in all aspects of the learning process were invariably observed.

Where there was no change in the control of the knowledge-base or where its use was relatively unimportant, such as when the computer was used to display experimental data, there was little difference in classroom strategies between lessons involving the use of a computer and more 'normal' lesson types. However, at the tactical level, there did appear to be some increase in active pupil-participation in teacher-class exposition or dialogue.

To facilitate the discussion of the observed changes, this chapter will consider their importance in three areas:

i) their impact on those directly involved in the teaching and learning process;

ii) the implications for the organisation and management of the classroom;

iii) the implications for program designers.

IMPLICATIONS FOR THE TEACHING AND LEARNING PROCESS

Changes in Classroom Strategies

Traditionally, teaching is seen as the active part of classroom life and learning seems to be viewed as its opposite rather than as its complement. Learning is seen as a passive activity, in which the learner is expected to absorb what is taught without having any direct control over the nature or the content of the teaching, or of the learning process itself. While such a view of classroom strategies is doubtless exaggerated, many of the 'theory' lessons observed in this study would support a somewhat passive view of pupils' learning strategies. However, pupils can become interactively involved in otherwise 'theoretical' topics and several alternative approaches to a problem can often be attempted in a short time if a computer is used.

Teacher-Based Change

The greatest changes in teaching strategies observed in this study occurred when the micro was used to replace or augment a traditional 'theory' lesson (see pp 102-107 and 145-160). In such circumstances, the work of Teachers 1 to 5 showed a marked shift from the teacher-exposition ('Ew') lesson format to one in which the pupils worked in independent, small groups. (See pp 102-107 for Teachers 1 to 4 and 108-116 for Teacher 5). This move to group work itself necessitated other changes in the classroom. There were more, shorter episodes as the teachers moved from one group to another (pp 104-105) and the nature of the episodes themselves changed with 'explanation' and 'initiation' being replaced by 'coaching' and pupil-led events. The teacher came much more into direct contact with individual pupils than was the case in class-based lessons: s/he was able to listen to the pupils as they were working and so gain far better insights into how they were thinking (pp 108-116, 145-160). This closer contact with the pupils seemed to encourage the use of more open-ended, more demanding questions by many teachers (pp 102-107) and also allowed them to adjust the difficulty of their questions as and when appropriate (pp 155-160).

Individual work by pupils was only observed in lessons which remained strongly teacher-centred. In such lessons, the micro was used under the direction of the teacher in conditions which closely resembled the traditional 'theory' lesson: teacher-'exposition' to the whole class formed the basis of the lesson, with the micro being used to generate 'appropriate' examples; teacher-questions tended to be both more closed and less demanding than those used in the small-group settings (pp 161-170 and 176-185). At various times in the lessons, the pupils worked individually on set problems, returning each time to further teacher-exposition. The 'W1' episodes were characterised by (sometimes extended) periods of silence: there was little or no on-task vocalisation by the pupils and, consequently, only limited feedback available to the teacher.

If the move away from the class-lesson to a small-group structure is to be successful, the pupils must be able to work without the detailed, blow by blow teacher-direction which characterises most formal whole-class situations. Ideally, the pupils should have direct access to the knowledge they need and should be able to monitor and adjust their own progress. The observations showed that the use of a micro could support such lesson structures (pp 108-116, 134-139, 144-160) where the pupils had direct control of the knowledge-base. Individuals or groups could then make their own decisions and place their own interpretation on the feedback received from the program.

Because this use of the micro gave the pupils more control over their learning (in the short-term), the teacher could, to a large extent, avoid the role of task-setter (pp 102-127 etc.). Transferring the role of task-setter to the micro gave the teacher the time needed to act as a facilitator of the pupils' learning: the teacher could listen to the pupils and react to what was said, offering advice, suggesting alternative strategies or giving direction as seemed appropriate. In some cases the teachers saw themselves as learning with the pupils (pp 134-139). Such radical teacher behaviour as listening and learning marks a great departure from normal classroom practice! The ITMA team have recently reported a similar view of the change in the role of the teacher, referring to the teacher as a 'Fellow Pupil' (Fraser, Burkhardt et al, 1985).

At least four basic conditions must be fulfilled if programs requiring the use of a knowledge-base are to be used successfully, in terms of apparent pupil-motivation and progress:

i) the pupils must have direct control of the knowledge-base;

ii) the program should encourage the pupils to adopt an open-ended, investigative approach;

iii) the program should offer appropriate feedback to the pupils;

iv) the teacher should not be too directive and should not attempt to 'close' the program.

Cases where the teacher failed to ensure that these conditions were met have been reported in Chapter 3. In ELEMENT (pp 171-175) the knowledge-base available to the pupils was insufficient and the pupils made little or no progress in the lesson; FORMULA (pp 176-185) encouraged a 'closed' view of the topic and raised little enthusiasm amongst the pupils and the FERTILIZER lesson (pp 161-166) was very closely directed by the teacher, with the effect of suppressing real pupil-participation. To some extent, these failures may reflect poor management decisions on the part of the teacher, but the effect of program content and style may also be an important factor: this will be discussed more fully later in this chapter.

Much more successful class-management was observed with programs such as DECOMP, CONTACT, INDUSTRY and DALCO. In these, the micro was assigned the role of task-setter and the pupils were organised in small groups. The programs enabled each group to have direct control of the knowledge-base: for each group the micro posed the next stage in the problem, assessed the response offered and took appropriate action. Furthermore, these programs were essentially open-ended: there was no single, correct answer to the problems which arose. Because the teachers involved avoided using the programs simply to exemplify appropriate values, the programs were used successfully in an open-ended, investigatory manner, without the need for the teacher to be involved in administering an extensive knowledge-base.

The difference between CAL-based and non-CAL-based group work was clearly illustrated when a computer-based activity was compared with an equivalent pencil-and-paper activity (pp 108-116). In the pencil-and-paper activity, far more teacher intervention was required and the intervention itself was often directive and/or concerned with the transfer of facts from teacher to pupil. Much teacher-time was absorbed in providing basic information and checking the appropriateness of the pupils' decisions. The CAL-version was much more self-contained and the pupils were able to make good progress without this 'directive' teacher-intervention.

Individual teachers did not use one particular style of teaching when using a micro, neither did their experience with CAL seem to be an important factor in determining lesson style. Teachers 1 to 4 represented a wide range of experience with CAL, yet all were observed to use it in both whole-class and small-group situations and to use both 'open' and 'closed' strategies. The nature of the program itself appears to be important in this respect: even the same teacher/class combination will use very different strategies with different programs. This was illustrated by the work of Teacher 2 (pp 176-185). With FORMULA, there was clearly a 'right' answer to any given problem: this was not so with DALCO. FORMULA covered a traditional topic in the syllabus in a way which provided a close match to the traditional techniques and examples used. Thus, although the program could be used in an investigative manner, it is perhaps not surprising that the teacher responded to the program by adopting a traditional, teacher-centred strategy and using the program mainly as an illustrative aid. This type of response was commonly found when two conditions were satisfied:

i) the program provided a close match in content and style with what was traditionally taught;

ii) there was a definite, correct answer to the problems set.

That strategic changes occurred in CAL-based lessons is not surprising: the decision to use a micro itself represents a change in stategy for the teacher. However, the changes which accompanied this initial strategy-change marked a clear movement from a centralised, teacher-controlled approach, especially typified in 'theory' lessons, to a much more open, pupil-centred approach. A corollary to this was the change in the pupils' perception of their own and the teacher's role in the lesson and, hence, in the way in which they approached their work.

Pupil-Based Change

The changes in teaching strategies produced associated changes in the pupils' learning strategies. The move to group-work facilitated pupil-pupil discussion and provided a mutually-supportive environment within which the pupils could operate. The learning strategies adopted in small-group, pupil-centred lessons were much more open and investigatory than was observed in more formal, teacher-centred lessons. The shift to pupil control of the knowledge-base gave the pupils a greater responsibility for structuring their own learning situation (see pp 102-107, 145-153 etc.). The pupils were found to be willing to follow their own lines of reasoning, to suggest actions and to formulate hypotheses and to modify these according to the results of their actions (see pp 108-116, 145-153 etc.). This type of pupil activity was observed, for example, in CONTACT (pp 134-139), in their constant effort to reduce the 'cost' of the acid and also in DALCO (pp 145-153), in their attempts to arrive at an acceptable compromise in site, fuel etc. (see Tables 4.4, 4.5, 4.6).

It was not observed to nearly the same degree in any teacher-centred lesson. In teaching the Contact Process without a micro, the teacher could only have given typical reaction conditions, telling the pupils that 'a compromise had to be reached'. This would have given the pupils no opportunity to develop a 'feel' for how the reaction behaved and would have forced them to rely on rote-learning to memorise the final conditions.

In both DALCO and CONTACT, the 'mistakes' made by the pupils formed an essential part of the learning process: they stimulated on-task pupil-pupil discussions, which led the pupils to revise their earlier hypotheses and gain a better understanding of the principles used. Such generation, testing and revision of hypotheses is often a desired outcome of science lessons, but it is rarely observed outside the use of CAL. Programs such as DALCO and CONTACT do not attempt to give a 'correct' answer nor to demonstrate the accepted conditions. The pupils must generate their own solutions and this 'openness' seems essential in encouraging high-level pupil discussions. Overhearing the 'on-task discussions' gave the teacher new opportunities to make judgements about the pupils' learning and to give appropriate remedial help and/or encouragement.

Not only did the amount of on-task pupil-pupil discussion increase, but qualitative changes were found in the type of discussion taking place. In the work of Teacher 4 (pp 117-127) DECOMP was compared with a 'practical' lesson and in both lessons a considerable amount of on-task pupil-pupil talk was observed. The importance of the comparison lay in the qualitative differences in the content of the 'talk'. In DECOMP, the pupils tackled much more difficult issues: they asked 'why' things were changing rather than 'what' was changing. Similarly, in

CONTACT (pp 134-139) the pupils were found to be asking 'why' and to be offering hypotheses to account for the changes they, the pupils, observed. Such pupil-pupil dialogue appeared to be at a higher cognitive level than was found in teacher-centred and/or non-CAL lessons where pupil-'talk' was concerned with facts, rather than with the interpretation of the facts.

This change in pupil-talk was indicative of a change in the pupils' approach to the lesson. They no longer expected to be passive; they were willing to take an active part in structuring their own learning activities. Using the microcomputer allowed an environment to be established in which the pupils felt able to use the knowledge to which they had access: to follow a hunch; to test their ideas freely and to discuss the consequences of their decisions. The pupils were likely to treat teacher-intervention very much as they would have reacted to intervention by a peer: they responded freely, at length and, often, several pupils would become involved in the response (pp 145-160). Teachers' questions tended to be taken as starting-points, rather than tests, and the teacher, having moved away from the traditional role of task-setter, was less likely to be seen as the sole source of knowledge and direction in the classroom.

In considering the relationship between pupil-activity and the knowledge-base, the source of the knowledge seemed to be less important than who controlled its use. From the observations reported in Chapter 4, four different sources of teacher-independent knowledge-bases can be identified:

i) In DECOMP the pupils had had recent, extensive experience of the type of reactions which the program simulated and they appeared able to use this **internalised knowledge-base** to respond to the program without any external references. Where difficulties arose, one pupil was able to help another and 'coaching'-style episodes were observed to occur within a group of pupils, without teacher intervention.

ii) In ANIMAL the immediate knowledge needed was provided in the form of **reference books** and this, together with what the children already knew, was sufficient for them to use the program successfully. They showed no hesitation in offering ideas, nor in criticising the ideas of others.

iii) In DALCO, **printed material published with the program** provided the pupils with the information needed for their initial decisions, as well as aiding them in forecasting production and interpreting results. The pupils were able to combine this information with the 'new' information they generated within the program and to use it in their search for an acceptable solution to the siting and running of the aluminium plant.

iv) **Information generated by the program** formed the main source of knowledge in the use of the third part of the CONTACT program. The pupils had to combine two sources of information. Firstly, they had to use their own knowledge of rate and equilibrium effects - possibly gained from parts 1 and 2 of the program. Secondly, they had to interpret the results displayed in order to arrive at a usable ('profitable') compromise between ideal 'rate' and 'equilibrium' conditions.

It was the pupil-control of the knowledge-base which underpinned the changes in the pupils' learning strategies. It enabled the groups to function without constant teacher-intervention and provided the feedback essential for them to monitor and adjust their own progress.

Occasionally, it was found that no knowledge-base was available for the pupils. In the ELEMENT game (pages 171-175) not only did the teacher overestimate the extent of the pupils' knowledge of the subject, but he also failed to provide any 'back-up' materials to cover any deficiencies which could arise. Neither did he maintain the continuous 'exposition' style which characterised many teacher-centred lessons. The lack of both sufficient internalised knowledge and of external referents left the pupils with little alternative to guessing. Thus, although the pupils appeared to be encouraged, by the program, to take an active part in the lesson, they were unable to make good progress: they did not have effective control over the required knowledge-base.

In those CAL-based lessons in which the teacher remained firmly in control of the knowledge-base (see pp 161-185), the pupils tended to adopt a passive role: they made only those responses specifically requested by the teacher; their answers to questions were often diffident and many pupils seemed to expect to be wrong. The answers offered by the pupils were short and, usually, the response was confined to one idea from one person. Indeed, on some occasions, the pupils seemed to realise that their main task was to 'guess what teacher wants'. This pseudo-participation was clearly illustrated in the use of the FERTILIZER program described in pages 161-170. The teacher demonstrated that only choices which coincided with his own would be acceptable and the pupils responded by searching for those choices.

This 'passive' style of pupil-behaviour was observed in most 'theory' lessons and in some aspects of 'practical' lessons (see pp 117-127). The pupils adopted an active role as far as 'doing the practical' was concerned, but reverted to a passive role when it came to interpreting the results. Persuading pupils to take an active part in forming conclusions from practical work always appeared to be the most difficult part of the lesson for the teacher. Although the pupils were physically active during the practical, they still had little control over what they did or the order in which they did it: intellectual participation often seemed to be postponed until **after** the practical work; with CAL, intellectual activity was evident during the whole session. Throughout the series of observations, the most active pupil-participation occurred when the pupils had direct control of the knowledge-base: where it remained firmly in the control of the teacher, there was little 'real' pupil-participation.

Summary

For pupil-centred approaches to be successful, the teacher must be relieved of the role of task-setter and, for this to occur, the pupils must have effective control of the required knowledge-base. Where control of the knowledge-base remains with the teacher, the pupils have to turn constantly to the teacher for direction. Where the pupils have control, the teacher can become a facilitator of learning rather than a provider of knowledge. There is a change in the nature of the demands made upon the teacher's time, which appears to be potentially beneficial for both sides in the teaching and learning process.

Once the teacher has provided any necessary materials for the pupils to use, then the control of the use of the knowledge can pass to the pupils. With programs such as DALCO, CONTACT or INDUSTRY, the pupils actively pursued the sorts of aims the teacher would have set for a more formal lesson - but here they were pursued voluntarily, actively and with vocalisation of hypotheses and counter-arguments. While the goals themselves may have been set, covertly or overtly, by the teacher, the pupils **felt** free to pursue their own line of work, to follow their own ideas and to argue their case amongst their peers in a manner which was not observed where the teacher remained the task-setter. In doing so, the pupils provided the teacher with the feedback needed to make sound judgements about their, the pupils', progress.

Fundamentally, it is this transfer of control of the knowledge-base, made possible by the use of the microcomputer, which relieves the teacher of the task-setting role and allows a 'new', more active role to be pursued by the pupils.

Changes in Classroom Tactics

The changes in teaching and learning strategies discussed above allowed corresponding changes at what might be called the tactical or interpersonal level. The breaking-up of the monolithic 'class' into small groups made it easier for the teacher to approach individuals within the class to give help and advice and, perhaps more importantly, to listen to what was being said by the pupils. The existence of these independent small groups allowed the pupils to vocalise their own ideas in a way which was not observed in more teacher-centred situations.

Because the micro could provide pupils with access to a teacher-independent knowledge-base, its use in a small-group situation allowed a multitude of 'different' approaches to a problem. This, in turn, allowed the pupils to take a more active part in the lesson and their acceptance of this new, more active classroom-role affected the ways in which the pupils reacted to each other and to intervention by the teacher. The use of a microcomputer can provide strong support for teachers wishing to adopt a more open-ended, less directive approach in their work with their pupils. By performing the role of task-setter, the microcomputer frees the teacher from the immediate task of managing the knowledge-base. Thus, the teacher has the time to discuss, with groups of pupils, their ideas and the interpretation of their results, secure in the knowledge that the microcomputer will provide appropriate corrective feedback should a group make an inappropriate choice while the teacher is elsewhere.

Pupil-pupil interactions have generally taken the form of increased on-task talk and a greater facility in proposing hypotheses, albeit in the form of assertions and suggestions. The aware teacher can encourage an investigative approach within a group of pupils and build upon what is overheard of the pupils' thought processes.

Teacher-Based Change

Removing the role of task-setter does not lessen the teachers' work-load: it brings about a change of activity rather than a reduction in activity. When the computer is given the role of task-setter, then the teacher takes on the role of facilitator or supporter, encouraging and extending the learning activities of the pupils. In CONTACT and DALCO, for example, if the pupils made a 'mistake', they were not immediately given the 'right answer'. Instead, they were encouraged to rethink any inappropriate decisions, both by the response of the program and by the intervention of the teacher (see pp 134-139; 145-153).

This new role adopted by teachers also allowed, or encouraged, them to be more responsive to the pupils' needs in an open-ended situation. This was exemplified in the 'ANIMAL' program: initial teacher-questions tended to be open-ended and quite demanding, but when these were met with a null (or unsatisfactory) pupil-response, the teacher was able to rephrase the question in a less demanding and/or less open form without adversely affecting the flow of ideas from the pupils (pp 154-160; Table 4.11). This movement in the level of teacher intervention was observed in many CAL-based lessons (and in some non-CAL lessons) and appeared to be a commonly used tactic for maintaining the level of pupil-participation and/or assessing the extent of the pupils' understanding of the topic.

Both feedback from the program and from the teacher would seem to be necessary if the most effective use is to be made of the computer. Table 4.7 showed an example of open-ended teacher-feedback being added to the accumulated computer-feedback, to initiate the pupils' discussion of the appropriateness of their original decisions. While feedback from the computer may often be enough to stimulate further work, teacher intervention can have some benefits:

i) it can correct any mistaken impressions gained from the program;

ii) the accompanying teacher-pupil interaction can provide essential feedback for the teacher on the extent of the pupils' understanding of the problem;

iii) the teacher can extend the pupils' work into previously unconsidered areas.

Tables 4.5 and 4.7 showed that, where the teacher intervention was non-directive, the pupils were able to continue formulating their own arguments. In Table 4.5

the teacher was asking the pupils to explain their decisions: in their responses the pupils freely interrupted one another, each adding to the explanations offered. In Table 4.7 the teacher's questions were seen, by the pupils, as requiring a more specific response, yet they still felt able to offer multiple responses to a single question. This was never observed in a non-CAL or in a teacher-centred situation.

Teacher intervention can also have its drawbacks: if the intervention is directive, if it offers particular routes to success and/or failure, then there will be a return to the teacher-centred approach and, consequently, the amount of pupil-participation will be restricted. Examples of directive and non-directive teacher intervention were demonstrated in the work of Teacher 6 (pp 161-170), Teacher 2 (pp 145-153) and, within a single lesson, in the work of Teacher 5 (pp 108-116).

The work of Teacher 6 with the FERTILIZER program provided a sharp contrast to the lessons observed with CONTACT, DALCO etc., where the pupils had been free to speculate about the causes of problems and their possible solutions. Tables 4.12 and 4.14 show clearly the extent of teacher-control over the direction taken by the lesson. The questions which were asked appeared to restrict the pupils' activity to the selection of a suitable example: in fact, the teacher's responses made it clear that the pupils had to select the response the teacher wanted to use.

The extent of the teacher's control of this lesson had the effect of restricting the pupils' responses to short statements by a single pupil. This is not an uncommon occurrence in traditional 'theory' lessons, nor in teacher-centred CAL-lessons and it is indicative of tight teacher control of the knowledge-base. In such circumstances, the feedback available to the teacher by which s/he can judge the pupils' understanding and progress is extremely limited.

Pupil-Based Change

All the pupil-centred CAL activities observed in this study revealed a large degree of co-operation between the pupils within a group: a common approach was agreed upon - although often after much argument - and ideas were put forward, tested and supported or rejected by the group as a whole. In DALCO, this co-operative attitude was shown in the discussions about the choice of site (Tables 4.4 and 4.5), in which the teacher took a supportive rather than a directive role, and in choosing a power source (Table 4.6). The extracts quoted showed that the groups were able to resolve disagreements and to use their common stance as a basis for further work. Towards the end of the session, it became clear to the pupils that their original decisions had not been potentially the most profitable and the groups began to re-assess their original decisions. Their use of 'observations' - data generated by the computer - to modify their original model demonstrates the essence of 'scientific-method' and represents quite sophisticated behaviour for the fourteen-year-old pupils involved.

That the micro can facilitate such discussions may be particularly important in the middle (third and fourth) years of the secondary school, where pupils are notoriously sensitive to the opinions of their classmates and where whole-class discussions are difficult to generate and sustain.

Where competition between groups was specifically introduced, as in DALCO and in one of the three CONTACT lessons, then there was no co-operation between the groups. The pupils kept their ideas and progress 'secret' to avoid giving clues to the other groups. In contrast, where inter-group competition was not initiated, results were invariably shared between the groups. In the other two CONTACT lessons, for example, the various groups worked hard to reduce the 'cost' of the acid and ideas for improving the plant's performance were shared between the groups. The pupils were still obviously pleased when their own group had the 'best' results.

Individuals within a group were also observed to help each other, both in procedural terms and in understanding the ideas involved in a particular situation. Many examples of pupils 'teaching' were found in DALCO and CONTACT (pp 145-153; 134-139) and in other lessons in which pupil-pupil dialogue was allowed or encouraged (ANIMAL, pp 154-160; DECOMP, pp 117-127). The 'teaching' took many different forms including: direct instruction/exposition, giving examples and the use of suggestions and counter-suggestions. Under such circumstances, a genuine discussion of the ideas involved could take place: the pupils were more likely to express opposing views than had the teacher been giving the 'instructions' or 'suggestions'. Examples of teaching by pupils were not limited to the lessons involving the use of a computer, but, because of the greater opportunities for pupil-pupil discussion often found in these lessons, such 'pupil-as-teacher' activities occurred more frequently when the computer was used.

Considerable changes were found in the level of pupil-talk which occurred in the various lesson types observed. On-task pupil-talk was least evident in 'Theory' lessons, which were highly teacher-centred with the pupils in a traditionally passive role. In both 'Practicals' and small-group work in 'CAL'-lessons, there was a considerable amount of on-task talk and, in both cases, the pupils were observed to teach each other (pp 117-127, 134-139). However, the type of help sought and offered differed markedly in 'CAL' and 'Practical' work.

In 'Practical' work, the pupil-talk was very much content-based and dealt mainly with questions of fact or statements of procedure. The pupils concentrated on the details of the experiment, with remarks such as "What temperature do we use?", "How much do we add?" or "Stir it up" far outnumbering questions about the causes of the observed changes or explanations of the reasons for a particular procedure. While such simple statements were still present when CAL was used, there was a greater tendency to discuss such things as "What happens if we increase the temperature?" or "Why has the yield gone down?". The pupils were led to question the reasons behind the 'facts' generated by the computer model and to develop a 'feel' for the principles involved. This difference in the quality of pupil-talk was illustrated in the work of Teacher 4 (pp 117-127); the generally high level of pupil-talk in CAL-use can be seen in the use of DALCO, ANIMAL, CONTACT etc. Such programs encourage pupils to develop hypotheses which explain the relationships developed in the unit: the pupils' vocalisation of their approach to a set of workable hypotheses can provide their teachers with the information they need to make sensible judgements on intervention, assessment and future planning.

By supporting these changes in the nature of pupil-pupil dialogue in the classroom, the micro enables pupils to:

i) discuss the reasons for their suggested responses to the program;

ii) explain to each other their constructs of the principles underlying the unit;

iii) formulate hypotheses which enable them to predict the response of the program.

Summary

Throughout the study, microcomputers were observed to facilitate the use of small-group structures in the classroom and the increased security of such an environment may be an important factor in encouraging pupils to develop and discuss their ideas.

The appropriate use of software can allow the pupils to pursue fundamental scientific ideas in an apparently open-ended situation. The use of programs such as DALCO and CONTACT were seen to generate much on-task pupil-pupil discussion: they provided a mechanism by which pupils could put forward a hypothesis and test it within a 'secure' small-group environment. Because the problems set were open-ended and because the pupils had direct access to the required knowledge-base, they were encouraged to adopt an investigative approach to their work ("What if ... ?").

An increase in both the quantity and quality of on-task pupil-talk was commonly observed when the micro was used. Pupils readily made assertions based on their own interpretation of the 'facts'; they questioned the ideas of others and they were willing to test and modify their views as and when necessary. It appeared that the situation 'allowed' the pupils much greater freedom to vocalise their ideas, without the risk of losing face before the whole class. Certainly, hypotheses appeared to be suggested and discarded or accepted much more readily in this kind of small group environment, than in either a non-CAL group or a whole class discussion.

These intra-group discussions provided the teacher with excellent feedback on the nature of the pupils' thought-processes and on the extent to which they had appreciated the principles involved. Such 'insights' allowed the teacher to tailor events within the lesson much more closely to the needs of the individual pupil.

Underpinning all these changes in the pupils' learning behaviour in the classroom, was the degree of independence available to the pupils when the computer was used. The pupils were no longer so dependent on the teacher: they had more control of the knowledge-base and a much greater responsibility for making their own decisions and for interpreting the events which followed. Because they were working in a group, they had to adopt a common approach and they had to be ready to discuss their ideas and support their viewpoints. They often seemed to regard the teacher almost as a peer, in that they would freely discuss their ideas and offer solutions to him/her in a way that was not seen elsewhere. The pupils were observed to take on a role which was, in many ways, reminiscent of the role of students in Higher Education: they used an available knowledge-base to formulate and test hypotheses.

The changes outlined here are both complex and mutually interactive: teacher-initiated changes in lesson structure and content produce changes in the pupils' attitudes and responses; these modify the teacher's behaviour towards the pupils, which further modifies the attitudes and responses of the pupils. The teacher must be prepared to allow and foster such change if CAL is to realise its full potential.

IMPLICATIONS FOR CLASSROOM ORGANISATION AND MANAGEMENT

In the course of this study it became apparent that certain styles of classroom organisation and management resulted in a high level of active pupil-participation in the lessons, whilst others seemed almost to suppress such activity. Without doubt, small-group work on problem-solving activities produced the greatest apparent pupil-participation.

Managing Small-Group Work

The physical organisation of small-group work for CAL-based lessons involves little that is new for most science teachers, who are used to such organisation for 'practical' lessons. However, the approach adopted by both the teacher and the pupils in CAL-based lessons may be sufficiently different from their approach to other lesson-types as to raise a number of important management issues. The comparison of CAL-based lessons with other lessons showed four important areas of potential change:

i) the proportion of the lesson-time concerned with the discussion of strategies, results and the implications of these results may be much greater than in other lessons;

ii) the discussions may be at a different intellectual level;

iii) the need for close teacher-direction of the learning process may be lessened;

iv) the teacher's role may change from that of supplier of knowledge to that of a facilitator in the pupils' search for and use of knowledge.

If CAL is to be used to its full potential, then the teacher must be able to respond effectively to these changed circumstances.

In most cases, there is likely to be only a small number of computers for the class to use and keyboard time is likely to be at a premium. If, as suggested in (i) above, there is to be a considerable amount of discussion, then the teacher should be able to organise a routine of 'keyboard' and 'non-keyboard' activities relatively easily. If the computer is being used to support practical work, then it may become one of a circus of activities with relatively little change in classroom organisation. In either case, sufficient supporting materials should be provided to allow the pupil-pupil discussions to develop along useful lines. By judiciously arranging the groups so that their discussions can be 'overheard', the teacher can gain a detailed knowledge of the pupils' levels of understanding: such knowledge would not be available in a more traditional situation. In such circumstances there is a great temptation to intervene where the discussion does not follow the conventional wisdom of the topic concerned: the practising teacher should be aware of this temptation and consciously resist it. Much effective learning can take place when pupils have to correct their own mistakes, or when they have to explain to others in the group why a particular course of action went astray (e.g. DALCO, CONTACT). The observations in this study showed greatest apparent pupil-activity when teacher-intervention rates were low and when the intervention which did occur was not overly directive.

Where more keyboard time is needed, the mode of use of the program should be carefully considered. In DALCO, for example, each group needs to complete a ten-year cycle of production at the chosen plant before the next group can start: this can take twenty to thirty minutes. To use the program to its best advantage, the pupils need to see the results for plants with differing production capacities and different sources of power built in different locations. Recognising that this might take too long - there may be only one computer and a large class - the program can be set to run the cycle on conditions fixed by the pupils. In this way, the effect of changing the major decisions (plant size, site and power source) can be checked in just a few minutes: the group can then leave the keyboard while they decide on which options would be most appropriate. The pupils could be encouraged to pool their knowledge, so that only two or three of the choices needed to be completed in full detail.

In all cases, care should be taken not to pre-empt the pupils' decisions: it is in the making of choices and the interpretation of their consequences that the most valuable learning takes place. Given sensitive management by the teacher, the pupils within the group will readily formulate hypotheses and suggest ways of testing them. Within the group again, they will freely argue for and against particular ideas on the basis of the information to hand. Such discussions of cause and effect, of interpretation of results and reconstruction of ideas, can be seen as being at a much higher level than that usually 'overheard' in the classroom.

The increase in pupil-led discussion forms just one aspect of the way in which the role of the teacher can be changed when CAL is used. In other ways, too, the need for overt teacher-intervention and for close direction of the learning process may be lessened. To a greater or lesser extent, the micro takes over the setting of the task and the monitoring of the pupils' progress. The teacher is able to become a facilitator of the pupils' learning and, as such, he can develop a greater awareness of the strengths and weaknesses of the individuals in the class.

To be successful as a facilitator, the teacher must predict the routes likely to be taken by the pupils and must provide appropriate resources. He must also be familiar with the workings of the program and with its strengths and weaknesses: in particular, he must know the limitations of the model used and how well this reflects 'reality' or current theory. He should also be ready to lead the pupils to an awareness of these limits and to the usefulness of models in general in the scientific process.

Teacher-Centred Use of the Micro

The use of the micro by the teacher in a whole-class situation can also be very valuable where it is used to illustrate a particular teaching point, an idea or a theory or where it is used in conjunction with an experiment. It is much less successful, in terms of active pupil-participation, when it is used as the basis for a lesson in 'teacher-exposition' mode.

If the lesson consists, essentially, of the teacher standing at the front and talking, then the micro can be regarded as a teaching-aid in much the same way as an OHP or the apparatus used in a demonstration. The conditions necessary for the pupils to take an active part in the 'CAL' lesson are essentially the same as for other lessons: there must be a good working relationship between pupils and teacher. Active pupil-participation in the lesson is not a matter of one of them working at the keyboard (although the teacher may find this convenient): it is, rather, the open exchange of ideas between pupils and between the pupils and their teacher. Such interchanges in teacher-centred lessons would seem, almost certainly, to be based more on the teacher-class relationship than on any special effectiveness of CAL as a teaching aid. This was demonstrated most clearly by the comparison of the ways in which Teachers 3 and 7 used nearly identical software and hardware when using the micro to investigate variations in the rate of the acid/thiosulphate reaction. Using a micro will not, of itself, improve a poor teacher-class relationship. It will, however, present new opportunities for the aware teacher to interest and inform his/her class about the topic in hand.

Pupil-participation in a lesson is also markedly suppressed if teacher-control of the direction of the lesson is too tight. The use of the FERTILIZER program by Teacher 6 provided an example of 'tight control' and the lack of active pupil-participation was apparent throughout. If 'real'-participation occurs when the pupils take an active part in the decision-making processes of the lesson, then pseudo-participation was demonstrated in this lesson (and elsewhere). The pupils soon realised that they were to have little real choice in what examples were chosen or even in what values were used. The pseudo-participation which followed this realisation consisted of the pupils trying to 'guess what teacher wants'. Pupil-vocalisation was reduced to a minimum: spontaneous suggestions were absent and elicited responses became almost monosyllabic. Feedback to the teacher of the pupils' level of understanding was, therefore, very much reduced. This must be seen as making effective teaching more difficult.

A similar effect on pupil-participation has been reported in studies of mathematics lessons by the ITMA project: in rating "how highly involved the children appeared to be", observers consistently gave higher scores in more open-ended, more demanding situations (Fraser, Burkhardt et al. 1985, p 34, Table D).

Some teachers, perhaps, feel less secure when a significant part of the control of the lesson passes to the pupils. For them, it would be natural to resist such changes, avoiding the situation by maintaining control of the knowledge-base and using the micro simply as a teaching aid within a formal, whole-class structure. However, observation has shown that many teachers can cope with this transfer of control, making good use of the many benefits which arise. It should be emphasised that 'pupil-control' refers to the pupils having a significant degree of control over the learning progress in a lesson: it does not imply pupil-control of the syllabus and certainly does not imply a lack of control by the teacher in any area. In 'discovery-learning', we expect the pupils to 'discover' for themselves what is already known to others: the 'discovery' is guided by the teacher, if only by the selection of what is available to the pupils. Similarly, in 'pupil-control' of the learning process, the teacher will already have selected the software and the supporting material and will have tried to anticipate and cater for likely pupil-responses. It is the pupils' perceptions of the process which are important. They respond to a topic most readily when they feel that they have a real choice in what happens: that the topic and supporting materials have been selected by the teacher, appears to be a separate issue.

This view of the micro, as enabling the pupils to work independently of the teacher, has also been supported by the work of the ITMA team (ibid). They suggest that pupils imbue software with an independent personality with which they can react: the computer shares management and task-setting roles and enables the teacher to act as a 'counsellor' or 'fellow-pupil' in a way which promotes higher-level learning activities.

Summary

The conditions for successful teacher-led use of the micro are generally similar to those for success in small-group use: the pupils must feel directly involved in making the choices and in interpreting the results and they must feel secure in their relationships with the others (including the teacher) involved in the work. The use of CAL will not, of itself, guarantee a wider range of teaching nor the engendering of higher-level skills in the pupils, but it can provide many new opportunities for such activities and so allow both teacher and pupils to improve their respective performances.

IMPLICATIONS FOR PROGRAM DESIGNERS

This study has concentrated on the effects which the use of the computer has in the classroom and has deliberately avoided any direct attempt to evaluate particular CAL-units or to compare one unit with another. However, some general points have arisen which are fundamental to the educational design of CAL units.

The degree to which pupils took an overtly active part in the lesson varied greatly between one teacher-class combination and another. Perhaps more interestingly, for this study, was the almost equally great variation for the same teacher-class combination between one lesson and another. For those lessons involving the use of the computer, one of the factors affecting this participation was the nature of the program used in the lesson.

To stimulate the greatest degree of active pupil-participation in a lesson, the design of a CAL unit must satisfy four conditions:

i) the pupils must have effective control of the knowledge-base;

ii) the program must allow an open-ended, investigative approach to be adopted;

iii) the program must give appropriate feedback by which the pupils can make effective judgements regarding their own progress;

iv) the program must be suitable for use by small groups of pupils.

These conditions are similar to those which the opening section of this chapter (page 193) suggested that a teacher would require: they will now be discussed in more detail.

Control of the Knowledge-Base

'Effective control of the knowledge-base' means that the individual pupils concerned must have direct access to the information they need to make best use of the program. This need not be provided 'on-screen', nor even be directly provided in printed material associated with the unit. It must, however, be available to the pupils at the time the computer is in use and without the intervention of a third party (such as the teacher) being necessary.

Some of the lessons discussed in Chapter 4 provide good examples of the different ways in which access can be gained to the knowledge-base. In Part 3 of 'CONTACT', the information needed for the interpretation of the results was given 'on-screen'; the worksheets provided with the unit and those produced by the teachers concentrated more on the mechanics of running the program than on the information needed to keep the plant 'profitable'. 'DALCO' provided a wealth of printed information - text, graphs, maps - on the aluminium industry and on the available sites for the plant. Pupils needed to use the information carefully to be able to make forecasts of the demand for aluminium and to cope with all the other factors involved. With 'ANIMAL', however, neither printed material nor on-screen information was provided by the CAL unit. Instead, the teacher provided a large stock of reference books which the pupils were able to use freely in conjunction with the program. In DECOMP and ELEMENT, the teachers expected the pupils to use existing, internalised knowledge to interpret the output of the programs. Such work can allow the pupils to see the facts in a new light and can generate a new understanding of the relationships involved. This appeared to work well in DECOMP (pp 117-127), where the pupils were able to explain the graphical output of the program in terms of the 'reaction conditions' used. It was less successful in ELEMENT (pp 171-175), where the pupils had not 'internalised' enough of the basic facts.

In each case where a knowledge-base was available, once the lesson had started, the pupils were able to make good progress without the teacher having to act as an intermediary. This not only freed the teacher for other tasks within the classroom, but also made the pupils more responsible for their own learning experiences and, hopefully, allowed them to gain new insights into the subject matter concerned. Certainly, it enabled a move away from simple consolidation/imitation exercises and encouraged an investigative problem-solving approach.

The program designer must, therefore, be clear not only about what information is needed by the program users, but also about the sources of the information and the most appropriate way to present it. If the information is to be published with the CAL unit, then a balance must be found between micro-based and paper-based information. This will, in turn, depend on the classroom organisation envisaged and on the presumed effective computer-time available to each group of pupils. If the information is to be sought elsewhere, then exemplars must be given and their modes of use described: it cannot and must not be assumed that all teachers will make equally good use of the given material.

Open-Ended Approach

If a CAL unit simply facilitates drill and practice or if its approach to a problem too clearly indicates the author's view of the 'correct' approach to a single 'correct' answer, then there will be little opportunity for an individualistic approach by the pupils. In such cases, pupils are effectively denied the kind of opportunities offered in more open-ended situations and they appear to feel restricted to searching for 'the answer teacher wants'.

Programs which may have been intended to be used in relatively open-ended situations will, nevertheless, often be treated as 'closed' if they are perceived, by the teachers, to be content-based. This is especially so where the program content and the approach taken by the designers are matched too closely to traditional ways of approaching theoretical aspects of the subject. For example, 'FORMULA' allowed a selection to be made from most of the elements and radicles normally encountered in an 'O'-level chemistry course: it placed no particular restriction on the examples chosen, the values used or the order in which problems were chosen. However, it was seen to be used in a highly-structured, closely-directed style of teaching in which the computer was, in many respects, simply a substitute blackboard (pp 176-185).

If program designers wish their products to be used in an open-ended style, then they must make positive efforts to encourage and support such activities. Pupils will be most actively involved if the program design allows them to control their own route through the program, to choose their own examples/values and to alter previous decisions in the light of feedback from the program. The teacher too must be encouraged to adopt an open-ended approach. This is perhaps most effectively done by including, in the Teachers Notes, suggestions for the use of the program which are firmly based in good classroom-practice rather than in the application of the program to the content of a particular part of the syllabus. The use of computers in the classroom is still a relatively new phenomenon for many practising teachers and examples of good practice can be a valuable starting-point for lesson planning.

Feedback

The precise nature of the feedback used will obviously depend on the nature and content of the program and on the time taken to work through one 'cycle'. Whatever feedback is used, it should not simply give the 'correct' answer: its aim should be to encourage the pupils to correct their own mistakes by critically reviewing their model, their strategy or a series of decisions. Programs which always give 'the answer' can too easily degenerate into a 'page-turning' or 'button pressing' exercise needing little thought from the pupils

One of the claims made for CAL is that it can provide a secure learning environment, in which the pupil can formulate and test hypotheses without the risk of 'losing face' before the teacher or the whole class. Such claims must be seen as predicated on the CAL unit providing sufficient feedback, at appropriate times, to allow the student to maintain a sense of progress and achievement. At the same time, the feedback must not be overtly corrective. In CONTACT, for example, there is no single 'right' set of conditions and there are no congratulatory messages in the program: the feedback is simply data, generated from the pupils' chosen conditions, concerned with the chemistry and economics of the manufacture of sulphuric acid. Such apparently non-judgemental feedback can be seen to have obvious benefits: choices which, in other circumstances, might simply have been seen as errors needing correction, now form the basis for further work. The initial 'judgement' comes from the pupils and not from the teacher or program designer. During the observations in this study, the pupils showed themselves capable of using the data produced by the program, both as a basis for generating hypotheses, which related changes in conditions to reaction outcomes, and as a means of 'fine-tuning' the reaction.

Program designers should always treat feedback from their programs as a way of stimulating further work and of generating new insights: it should not be thought of simply as a way of correcting what the pupils have done wrong. However, care must be taken to balance the impact of the various forms of feedback used. In DALCO, for example, there are a number of 'environmental warning' messages used in the early stages of the decision-making, which appeared to have a marked influence on the pupils' choices (pp 145-153). Once the site had been chosen, however, these messages stopped and the pupils were presented with balance sheets for each year's trading accounts. The pupils then began to place much greater emphasis on financial success and to examine their earlier decisions in a new light. Such clear links between the feedback given and the pupils' responses demonstrate the need for care in the design and timing of feedback. The teacher must be made aware of the purpose of the feedback and of its possible implications if hidden and/or unintentional messages are not to be transmitted to the users.

Small-Group Work

Throughout this study it has been observed that the most active pupil-participation ocurred when the class was organised for small-group work. The great advantage small-group work has over both individual and whole-class work is that it can provide a secure, mutally rewarding situation in which new ideas can be explored.

It is often difficult for pupils to respond freely in a whole-class situation, where they may be subject to censure of one kind or another from their class-peers. This both restricts the interchange of ideas between pupils and reduces the information available to the teacher about the pupils' levels of understanding. This lack of active pupil-participation often results in the class-lesson being far more didactic than its group-work counterpart.

In the single-pupil situation, the pupil mainly receives feedback from the program, turning to the teacher when help is needed. There is little or no sharing of ideas and explanations between pupils and there are few checks, other than those built-in by the program designer, on the pupil's development and progress. As there is, generally, no vocalisation of ideas, there is, again, little feedback for the teacher.

In both cases, the pupils' ability to respond freely and in unexpected ways is restricted and their learning, at least from the teacher's viewpoint, becomes much less certain. By encouraging group-work, a program not only increases the active involvement of the pupils in the learning process, but also provide a better model of work-patterns in 'the real world' and of the approach to problem-solving in general.

For programs to be usable by small-groups, the designers should ensure that:

i) the screen can be read by all group-members;

ii) the required tasks can be shared amongst the group or solved by a team-effort;

iii) intra-group discussions are explicitly encouraged by the program design and in any associated printed material;

iv) any Teachers Notes published with the unit stress the advantages of a group-approach from educational and class-management perspectives;

v) the keyboard time required for any one session is relatively short or, where appropriate, the program can store the position reached by one group, while another group tackles their part.

Group-work is not simply a matter of sharing the time at the keyboard: the task set should be meaningful to the group as a unit. It should present its target audience with a task which is sufficiently complex to warrant some discussion of their response. A balance needs to be struck between the task being trivial and being so difficult that the pupils are reduced to guessing. The discussion need not, of course, take place at the keyboard. It may often be more appropriate for the pupils to go elsewhere to discuss their choices and their interpretation of the computer's responses, thus freeing the computer for use by other groups. While teachers often strive to implement this kind of use in their classroom, there are relatively few programs which make specific provision for independent, multi-group use.

Summary

Those involved in designing a CAL-unit have to consider, inter alia, educational aims, target audience, screen design and how the program is to be driven. However, this study (and others) has shown that, while these factors are a necessary part of the process, they are not, in themselves, sufficient to produce an effective unit.

The expected mode of use of the program is a central issue and the designers must carefully balance what the program does and what the user is expected to do. If pupils are to work independently of the teacher, they need to have direct control of their access to the required knowledge-base. The sources of this knowledge - external reference books, on-screen information, accompanying worksheets, internalised pupil-knowledge - must be considered explicitly in the program design and stated clearly in any teacher-guides produced to support the unit. The program itself should leave sufficient scope for the pupils to work in an open-ended manner and the feedback it provides should encourage the pupils to improve their performances and not simply correct their errors. While most programs can be used in a variety of situations, those which encourage an exploratory group-work approach will generate the greatest amount of high-level, pupil-pupil discussion and involvement.

Chapter Six

Summary of the Findings

Introduction

In any series of classroom observations it quickly becomes apparent that not all lessons are equally good and, where CAL is involved, that not all programs achieve their desired effect. However, observations of many different classroom settings have shown that the use of CAL can produce effects of a type which are widely believed to be beneficial in terms of pupil motivation, progress and understanding.

The most clearly observed marker for these successful CAL-based lessons was the control of the knowledge-base by the pupils rather than by the teacher, especially where the task was open-ended or where the route to a desired end was open to investigation by the pupils. The effects of this pupil-control of the knowledge-base were clearly evident in such programs as ANIMAL, CONTACT, DALCO and DECOMP. This transfer of control allowed major changes in classroom organisation and in teacher and pupil roles.

Classwork and Group-Work

Throughout the observations, the principal use of the micro was seen to be as an alternative to 'theory lessons', with the main 'theory lesson' activity of exposition ('Ew') replaced, at least in part, by small-group work. Some of the teachers observed often used group-work activities in 'theory' lessons, while others normally used exposition. Table 4.1 showed that teachers with these different basic styles all used group-work structures far more in CAL-based lessons than in theory lessons.

As corollaries of this move to group-work, it was found that there were more - and therefore shorter - episodes in lessons involving group-work (Table 4.2) and that there were marked differences in the types of episodes observed (page 105). The shift to 'coaching' episodes noted here was indicative of there being a much greater emphasis on direct contact between the teacher and an individual pupil or small group of pupils.

At the 'event-level', too, the introduction of the micro was observed to bring about marked changes in the nature of the pupil-pupil and pupil-teacher interactions. There was a move away from simply questioning the facts of the situation, to examining the underlying reasons for those facts. This was very evident in the use of programs such as CONTACT, where the pupils were heard to ask, "Why has the yield gone down?" (p 137) rather than the more commonly-heard, factual question style of, "What is the yield?" or "Has the yield gone down?". The use, by pupils, of higher level questions, assertions and explanations did not appear to be simply related to the introduction of group-work. It was, rather, a function of how they interacted with the micro during the group-work.

Even in practical work, where group-work has long been the established norm, the pupil activity tended to be at a relatively low level: pupils clearly perceived the teacher as the source of information and feedback. Inter-pupil questions and assertions tended to be low-level and concerned very much with checking the experimental details rather than interpreting the results of the experiment. A typical practical-work, pupil-pupil question would be, "Is it 60°?" (p 123) in marked contrast to the equivalent simulation-based question, "How do you know it's finished?" (p 126). In the latter case, one pupil was asking another to explain her interpretation of the 'results'. In most practical situations, 'interpretation' was left to the teacher and often occurred in a 'whole-class exposition' at the end of the lesson.

Again, the independence of the pupils' interaction with the micro is important if 'exploration' and hypothesis testing is to occur. In the ELEMENT lesson (pp 171-175), the pupils clearly lacked independent access to the necessary knowledge and were forced to rely on guesswork or on intervention by the teacher. This effectively prevented them from making good use of the feedback provided by the program and from developing their ideas of the relative value of the 'tests' available.

In both 'practical' and 'theory' lessons, the pupils perceived the teacher as being very much in control of the knowledge-base and, so, turned constantly to him/her for help and reassurance. Questions from the teacher were often seen as 'tests', perhaps because the pupils were aware that the teacher knew 'the answer'. Pupils rarely showed any awareness that 'the answer' was only a 'model' of the true situation and that it would only be 'right' for a limited set of conditions.

Independence and Exploration

The increase in the extent to which the pupils worked in an independent and open-ended manner, when CAL was used, has been shown to depend upon their having access to sufficient knowledge on which to act without continual reference to the teacher for facts, for approval or for 'what to do next'. The INDUSTRY lesson (pp 112-117) revealed a marked difference between those using and not using the computer: those using the computer had, effectively, a much greater level of independence than those working through the 'pencil-and-paper' exercise. This was reflected in the extent to which the teacher directed the work of the latter groups through the use of low-demand, closed questions and simple assertions (see the extract on page 112).

Wherever the micro was used to give the pupils control of the knowledge-base, the pupils were able to explore scientific models and to test their perceptions of these models within the group. In DALCO, for example, the pupils were able to use the available information to formulate arguments for the different possible sites (Tables 4.4 and 4.5), without having to seek help from the teacher. They were then able to explore the consequences of their decisions and to review their original decisions in the light of the feedback generated by the computer (Table 4.7). The program involved the pupils in assimilating much new information, assessing its relative importance, predicting the likely outcomes of decisions, testing these predictions and, finally, reassessing their initial ideas. All of these can be seen as educationally desirable activities: all except the first are difficult to achieve in the traditional classroom.

At first sight, it may seem that practical work would generate many of these 'desirable' though 'difficult' activities. In practice, however, it is difficult to maintain an open-ended approach to a practical situation at a school level. Even the choice of apparatus and chemicals can be seen as pointers to a desired end and the constraints of time and examination syllabuses are seen, by many teachers, as preventing 'discovery learning'. By contrast, computer simulations of practical situations appeared to encourage both pupils and teachers to adopt a more exploratory approach and to 'try' a range of conditions and reagents.

Even with the micro, it was observed that, where the pupils did not have control of the knowledge-base, they were unable to make progress without resource to the teacher. In such circumstances, the pupils tended to work at a low level and to rely on the teacher to provide answers as well as information. This can be seen, for example, in the use of the FERTILIZER program (pp 162-167), where the evident desire of the teacher to take a pre-ordained route through the lesson led him to control the choice of examples and the interpretation of the results. The effect of this was to restrict the pupils to low-level interactions and to prevent any real exploration of ideas.

Teaching and Learning

Because the micro could support the pupils' work in a variety of ways, by giving access to the necessary knowledge, by providing feedback to the pupils and by monitoring their progress, it allowed and encouraged a number of important changes in the classroom roles of the teacher and the pupils.

Perhaps the most easily observed of these changes was the decline of the pedagogue. The teachers, generally, became less directive and acted as facilitators of their pupils' learning rather than as instructors. This change was apparent at all the levels of the SCAN records. There were changes at the 'Activity' level from 'exposition' to group-work; at the 'Episode' level from 'explaining' to 'coaching'; whilst at the 'Event' level there was an increase in both the 'level of demand' and the 'open-endedness' of questions, explanations etc. With programs such as CONTACT, DECOMP, DALCO and INDUSTRY, the teachers did not need to transmit information: the pupils would gain the necessary information from working with the programs. Instead, they were able to 'overhear' the pupils' thought processes and could, therefore, intervene in a more sensitive, thoughtful and open-ended manner than was possible in non-CAL lessons. For example, in Table 4.5 the teacher says "Jilly has a suggestion here ...... What was your argument for going to Whittington?". In this way, the teacher was able to encourage the examination of alternatives without the pupils feeling that a particular course of action was being prescribed.

In programs such as CONTACT, the mathematical model used was too complex for the teachers to be able to predict the actual outcome of any given set of conditions: all they could do was to predict trends. In a similar way, the random fluctuations in the demand for aluminium in DALCO prevented accurate forecasts of profit and loss, although trends could again be predicted. Such situations had a marked effect on the approach of both the teachers and the pupils. They saw each other as being more nearly equal in forecasting outcomes, with the result that the pupils felt able to discuss ideas, to make suggestions and to disagree with the teacher and others in a way that was not observed outside CAL lessons. Program style was, obviously, an important factor in stimulating these changes. To use Table 4.5 as an example again, a simple instruction from the teacher (line 30) elicited responses from all four of the pupils in the group and an attempted intervention by the teacher was ignored as the pupils continued to provide reasons for their choice.

Where a program is used in an expository manner, the teacher is much more likely to remain in the traditional role of the pedagogue. One clear example occurred in the FERTILIZER lesson (Table 4.12), where the teacher asked the pupils to choose " ... something you'ld like to eat." In response to one pupil's choice of "carrots", he said:

> "Carrots. You'ld like carrots .....
> Shall we try strawberries to start with?
> We'll try strawberries .....
> So we've chosen strawberries ..... "

The teacher was clearly controlling the access to the knowledge-base: examples, answers and requests for information all had to be routed through, and accepted by, the teacher. Choice for the pupil was reduced to choosing that which the teacher found acceptable, while open-ended, investigatory work was kept to a minimum. Similar examples could be found in LENS, in FORMULA and wherever teachers remained in their traditional roles.

The contrast between the two approaches was also apparent in the role adopted by the pupils. Where the teacher remained in the traditional pedagogical role, the pupils remained in the role of 'acceptors' of knowledge. Their role was confined to imitation and confirmation activities. In the LENS program, for example, the teacher chose the initial examples, encouraged the pupils to choose similar ones and asked them to produce diagrams on paper similar to those generated on the screen. There was little pupil-pupil talk in this lesson and pupil-responses to the teacher's questions were short and factual.

In lessons such as CONTACT, DECOMP, DALCO and ANIMAL, the teachers adopted a group-based, open-ended approach in which the pupils could gain access to the required knowledge without teacher intervention. The effect of this on the pupils was marked: they clearly felt able to discuss their ideas, with each other and with the teacher, much more freely than was usual in a traditional classroom situation.

The use of the micro allowed the pupils to take on more responsibility for their own work and for the work of others. In explaining their own hypotheses and interpretations, they were acting as 'pupil-teachers'. Indeed, it was not uncommon for one pupil to explicitly ask another to explain his/her ideas or interpretation of events (p 126). The pupils also began to perceive the teacher as what Fraser and Burkhardt call a "fellow-pupil" (Fraser, Burkhardt et al. 1985) and to treat teacher-intervention in a very similar manner to intervention by another pupil, freely responding to questions, assertions and suggested explanations with their own ideas and interpretation of events.

Talking and Listening

Much of what has been said in this chapter (and earlier) has relied upon the fact that the use of the micro can enable the pupils to talk and the teacher to listen. Such a reversal of the normal classroom roles should be seen as providing new opportunities for the pupils to develop and test their ideas and for the teacher to listen to this process and so gain a more intimate understanding of the problems and successes of the individuals in the class. By judiciously 'overhearing' the pupils at work, teachers gain a detailed feedback from them of a kind which is unavailable in other classroom-settings. By discussing their 'mistakes' with each other, pupils gain new insights and 'mistakes' become a part of the learning process, rather than a place at which to stop.

Studies and reports on various areas of the curriculum have all commented on the importance of the pupil-based discussion in the learning process (Bullock, 1975; Cockroft 1981). They also commented on its minimal place in many classrooms. The observations on which this study is based have revealed many instances in which both the quantity and quality of on-task pupil-pupil discussion increased when CAL was used in open-ended, pupil-centred activities.

Active pupil-participation in discussions was rarely found in teacher-centred lessons, even where the micro was used. The FORMULA, FERTILIZER and LENS lessons all provide examples of minimal pupil-based discussion in such situations. By contrast, lessons such as DALCO, CONTACT and ANIMAL were 'driven-along' by the enthusiasm with which the pupils discussed the issues as they saw them. The key-point here is that the pupils needed to be able to discuss the issues **'as they saw them'**, rather than via the teacher's perceptions. The teacher, therefore, should not intervene unecessarily and should take care that his/her interventions are not needlessly prescriptive.

Obviously, the pupils can only work independently if they have some means of accessing the necessary information, testing its application to the problem in hand and obtaining appropriate feedback without teacher-intervention. The CAL unit provides important support in these areas, but the importance of the other members of the group as 'co-hypothesisers' and 'co-testers' should not be neglected.

The SCANs of ANIMAL and DALCO provide examples of the extent of on-task pupil-pupil discussion which can occur. It can be seen, for example, that the pupils made large numbers of assertions as they searched for mutually acceptable approaches to their respective problems (Tables 4.9 and 4.18). The pupils used series of assertions, suggestions and explanations to set out their 'hypotheses' and to modify, reject or accept those of others in the group. The comparison of the DALCO and FORMULA lessons also showed a difference in the level of the events which occurred: in the pupil-centred DALCO lesson, the events tended to be more demanding and more open than in the teacher-centred approach used in the FORMULA lesson.

Concluding Remarks

This study has shown that the use of the micro can facilitate group-work structures in the classroom and, more importantly, that its use can bring about changes in the apparent roles of the teachers and pupils involved.

When using the micro, pupils become more independent in their approach and appear more willing and able to 'explore' alternative solutions to problems. They are far less reticent about discussing their own views and far more open in their approach to interpreting the information generated or gathered in the lesson. They view the teacher less as 'the source of all knowledge' and more nearly as a member of the group: they are more likely to respond honestly and openly to intervention by the teacher.

The teacher's role shifts from being the provider of information to a supporter or facilitator in the joint search for solutions. Because of the support given by the micro, s/he can spend less time in managing the lesson - assessing progress, providing feedback, and initiating the next activity - and more in listening to the pupils and responding to their problems on an individual/small-group basis.

As has been said earlier, these changes can only occur if the pupils can work without having to turn constantly to the teacher for assessment, for approval or correction and for permission to proceed. The pupils must have direct, independent access to the knowledge-base needed for the lesson. They must be able to gather and/or use the necessary information, to respond to the data generated in the lesson and to formulate and test their own hypotheses, without the teacher appearing to prescribe particular actions, inferences or solutions.

In this study, the microcomputer has been seen, repeatedly, to enable and support such activities. Whenever such occasions arose, they were marked by changes in classroom behaviour which would widely be seen as beneficial to the teaching and learning process.

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APPENDIX ONE

ASSESSING SCHOOL PROVISION AND ACTIVITY

Since the start of this project in September 1980, there has been an extremely rapid increase in the provision of microcomputers in schools and in the (apparent) interest in their educational applications. Direct government intervention, through the Department of Industry, together with great public interest in microprocessor applications have undoubtedly played a major role in the growth of hardware provision. Coupled with the DoI scheme was a requirement for Local Education Authorities to provide in-service courses for teachers in the applications of microcomputers in schools, so that every school should have not only a micro but also some staff with, at least, a few hours training in its applications. However, the amount of educational software available was very small and its supply was increasing much more slowly than that of hardware: in any discussion of CAL with teachers, the demand was always for more "good quality" software.

Because so many aspects of the situation regarding CAL in schools were unclear - what micro's were in use, how many in a school, what software was in use, how much software was available, what help did the LEA's provide etc. - and because the answers to many of these questions could have a direct bearing on the software to be developed, it was decided to use questionnaire-survey techniques to assess the activity at both LEA and school department level.

LEA Provision for CAL

In the autumn of 1981, a questionnaire-survey was circulated to all education authorities in England and Wales to determine the level and nature of microcomputer provision in schools. The survey was intended to aid those involved in the development of Computer Assisted Learning (CAL) material by providing information about:

i) the extent to which the authorities are involved in the distribution and/or production of software in schools;

ii) the extent to which the authorities share software with each other;

iii) the types of micro's currently recommended by the authorities;

iv) other types of micro's in use in secondary schools and sixth-form colleges;

v) the numbers of microcomputers in schools;

vi) the provision of other computing facilities in schools.

It was known that several authorities maintained a catalogue of available programs and that some were involved in the production and/or distribution of programs for use in schools. It was expected that any authority involved in the production and/or distribution of software would maintain a catalogue of programs.

Each authority, therefore, was asked a series of questions concerned with :

i) whether they produced such a catalogue and, if so, how access to the catalogue was controlled and what the sources of the programs in the catalogue were;

ii) whether the authority was involved in the distribution of software from national and/or local sources.

Each authority was asked to provide information about the level of provision of computing facilities in its schools. It was felt that, to ask for the numbers of each make of microcomputer in each school, would involve so much work on the part of the respondents that the number of questionnaires returned would be very small. Instead, each authority was asked to give the number of schools with 0,1,2,3,4, and 5 or more microcomputers. It was hoped that this, together with the responses concerning software provision and the types of microcomputers in use, would give a reasonable outline of the type of provision in schools.

Whilst recognising the necessarily evanescent nature of data generated in such a rapidly changing situation, it was felt that the returns obtained from the questionnaire would provide both a basis for judgements about the development of CAL material in this project and an indicator of current trends in hardware and software provision in schools.

In January and February 1982, completed questionnaires were returned by 76 of the 108 Education Authorities circulated, yielding data on the computing provision in some 2643 secondary schools and sixth-form colleges within these authorities. For convenience, the results are discussed in two sections: 'software support' and 'hardware provision'. The percentages quoted are based on the 76 responses received.

Software Support

'Software support' refers to those activities by which the Education Authorities seek to support the development and/or distribution of software in their schools. The responses to this first section of the questionnaire are summarised in Tables A.1 and A.2.

Activity	Number of LEAs	Percentage of LEAs
Maintain a catalogue of programs	36	47.37
Have a catalogue in preparation	4	5.26
Organise a program exchange for locally produced programs	48	63.16
Make locally produced programs available outside the authority	25	32.89
Charge users outside the authority for these programs	5	6.58

Table A.1

Software-Related Activities of Education Authorities

Activity	Number of LEAs	Percentage of LEAs with Catalogue
Circulate the catalogue to their schools	29	80.56
Make the catalogue available to other authorities	17	47.22
Circulate the catalogue to other authorities	2	5.56
Distribute programs to their schools	31	86.11
Means of distribution :		
Disk or cassette by post	21	58.33
Via modem from mainframe	9	25.00
From Teachers Centres	3	8.33
Via school library system	3	8.33
At meetings/courses	4	11.11
Program sources used :		
Chelsea Science Simulation Project	31	86.11
Schools Council Project Computers in the Curriculum	31	86.11
Longman Micro Software	24	66.67
MUSE	26	72.22
local teachers	31	86.11
other sources	32	88.89

Table A.2

Activities Related to Software Catalogues

When examining the figures quoted in the tables, the following points should be noted:

i) the figures in Table A.1 are percentages of the total returns;

ii) the figures in Table A.2 are percentages of the number of authorities maintaining a catalogue;

iii) the figures quoted for the distribution methods used by the authorities total more than the 36 authorities which maintain a catalogue, because several authorities which distribute programs via remote terminals from a mainframe also use one of the other methods quoted.

In many cases, the respondents gave comments, in addition to the figures from which the simple percentages given in Tables A.1 and A.2 were derived. Two points, in particular, were most noticeable:

i) many of the authorities not producing a catalogue said that they were relying on the M.E.P. Regional Information Centres to provide this type of service;

ii) a great variety of 'other sources' were quoted (see Table A.2), most frequently references to other authorities. Other references included the National Computing Centre, local Teachers Associations, Polytechnics and Colleges of Further Education, and, for those authorities recommending the PET, the Petsoft library.

Given the number of authorities which do not collate program information for their schools and the diversity of program sources, it would seem that the services of the MEP regional information centres will be in great demand.

Hardware Provision

'Hardware provision' refers to the number and type of microcomputers available to schools and the makes of micro's recommended by the individual authorities. Table A.3 shows the number and percentage of authorities recommending each make of microcomputer. As many authorities were recommending more than one make of microcomputer, a third column has been included in the table, to show the figures for each make as a percentage of the total recommendations.

Recommended Microcomputer	Number of Authorities	Percentage of Authorities	Percentage of Recommendations
None	2	2.78	2.21
RML 380Z	53	73.61	38.97
Apple II	8	11.11	5.88
Commodore PET	26	36.11	19.12
Sharp MZ80K	1	1.39	0.74
Tandy TRS80	2	2.78	1.47
Acorn Atom	3	4.17	2.21
BBC micro	35	48.61	25.74
Sinclair ZX80/81	2	2.78	1.47
Other	4	5.56	2.94

Table A.3

Recommendations by Authorities

The figures show clearly the large number of authorities recommending the BBC microcomputer even though, at the time the data was collected, there could not have been much experience of the machine in day-to-day use. The figures for the BBC micro and the RML 380Z would suggest that, apart from the qualities of the machines themselves, the policies of the Department of Trade and Industry have had a major influence on the decisions made by the LEAs.

The majority of authorities reported that micro's other than the recommended ones were in use in their schools, almost all reporting more than one 'non-recommended' make. Table A.4 shows the number and percentage of authorities in which each type of 'non-recommended' micro is in use.

Micro	Number of Authorities	Percentage of Authorities
None	12	16.67
RML 380Z	16	22.22
Apple II	30	41.67
Commodore PET	35	48.61
Sharp MZ80K	12	16.67
Tandy TRS80	31	43.06
Acorn Atom	27	37.50
Sinclair ZX80/81	34	47.22
ITT 2020	7	9.72
Video Genie	6	8.33
Sorceror	4	5.56
Other	14	19.44

Table A.4

Micro's Other than those Recommended by Authorities

Table A.5 shows the number and percentage of schools with 0, 1, 2, 3, 4 or 5+ microcomputers.

Number of Micro's	Number of Schools	Percentage of Schools
0	187	7.09
1	1490	56.48
2	434	16.45
3	219	8.30
4	138	5.23
5+	175	6.63

Table A.5

Numbers of Microcomputers in Schools

The LEAs were also asked what other computing facilities were available to schools: Table A.6 summarises these 'other facilities'.

Type of Computing Facility Available	Number of Schools	Percentage of Schools
On-line connection to mainframe	668	25.27
Batch processing on mainframe	379	14.34
Mini-computer in the school	4	0.15

Table A.6

Other Computing Facilities

Many of the respondents reported that the use of mainframe computers by the schools was likely to be phased out as the provision of microcomputers increased.

School Chemistry Department Activity

The extent to which CAL was being used, in chemistry teaching in the schools likely to be available to this project, was assessed by a questionnaire-survey of all secondary schools in Leeds, North-East Derbyshire and the four South Yorkshire Authorities.

The questionnaire was designed to collect data in four general areas:

- i) the hardware available in the school and the facilities provided for its use;
- ii) the involvement of the chemistry department staff in the use of CAL;
- iii) the sources and amount of software used in teaching chemistry, its perceived quality and its use at various levels within the school;
- iv) some basic demographic data regarding the school.

In addition to providing some basic data about the current use of CAL in teaching, the returns to the questionnaire provided a means of establishing contact with a fairly large number of teachers who were using CAL in their schools. The data given in the questionnaire returns would enable schools to be selected for the trials of some of the material developed in this project; it would also give a possible source of teachers willing to take part in the lesson observations necessary for the planned evaluation studies.

In February 1982, a questionnaire-survey was circulated to the Heads of the Chemistry Departments in 192 secondary schools. By April 1982, 134 returns had been received, of which 124 had been completed, giving a nett yield of 64.6%. The returns were collated under a variety of headings as given below.

Computing Facilities

The first part of the survey was concerned with the computing facilities available in the schools. Table A.7 shows the type of computers to which the schools had access.

Type of Facility	Number of Schools	Percentage of Schools
Microcomputers	121	97.6
Minicomputers	5	4.0
Teletype	22	17.7
Batch	12	9.7

Table A.7

Computing Facilities

As expected, microcomputers were available in virtually all schools and a significant number of schools had access to other computing facilities, with one school in six having on-line access to a mainframe computer. As it was expected that the vast majority of CAL work would become microcomputer-based, it was felt to be important to gain an insight into the numbers and makes of the micro's in the schools, and their availability to the chemistry department. Table A.8 shows the distribution of various microcomputers in the schools.

Make of Microcomputer	Number of Schools with			Total Number	Percentage of Schools
	1	2	3+		
RML 380Z	59	9	2	70	56.5
Apple II	15	4	5	24	19.4
PET	9	12	13	34	27.4
Sharp MZ80K	4	2	4	10	8.1
Acorn	4	2	2	8	6.5
BBC	19	2	0	21	16.9
Others	4	3	2	9	7.3

Table A.8

Microcomputers in the Schools

Given the DoI initiative, it was to be expected, perhaps, that the RML 380Z would be the most widely distributed microcomputer. However, the figure for the BBC micro is particularly interesting: it was 'launched' only a few months before this survey was taken and yet had been purchased by almost one-third of the schools in the sample. This corresponds well with the acceptance of the machine by the Education Authorities as shown in the previous survey of LEA's. More recently, the BBC micro has been incorporated into the DoI scheme at both secondary and primary school level and it would seem likely to find its way into the majority of secondary schools in the near future.

In such a rapidly developing field as microcomputers, it was felt that the early attempts to standardise on a particular type of machine would be overtaken by events and that many schools would, in fact, be using more than one type of micro. Table A.9 shows that almost half the schools concerned had more than one make of micro - in fact some had four different makes - and this does not take into account mutually incompatible models of the same make. This has obvious implications for the CAL-user in areas such as the purchase and maintenance of software.

Type of Facility	Number of Schools	Percentage of Schools
More than one type of microcomputer	57	46.0
Specific room for the microcomputer	80	64.5
Microcomputers used in the laboratories	77	62.1
Science department with own micro	22	17.7

Table A.9

Other Facilities

At the time of the survey, almost two-thirds of the schools had a room specifically reserved for the use of microcomputers. Interviews with individual teachers have shown that these rooms were generally seen as the province of the 'computer studies' department and were only occasionally regarded as a general 'resource area'. This could, obviously, create access problems for the teacher wishing to use the micro's for CAL applications. School policy decisions can also have a restrictive effect on the use of CAL: in over one-third of the schools, micro's were not allowed to be moved into the laboratory. It must be doubtful whether, in these schools, a teacher would be willing to make the necessary arrangements to use the computers, unless the use of CAL was likely to dominate most of the lesson. This would, of course, tend to exclude the use of CAL as a means of illustrating a single teaching-point, and would discourage its integration into the day-to-day teaching of the department. A significant number of science departments were found to have a micro based within the department and, again, interviews with teachers suggest that this trend is increasing. Both the survey returns and interviews with teachers suggested that the majority of science departments considering buying a microcomputer would choose the BBC micro or, less often, one of the Sinclair models. It may, however, be some time before sufficient good quality software becomes available for the departments to make full use of their microcomputer's potential.

CAL Usage

One of the functions of the survey was to aid the selection of teachers and schools to assist with the 'observations' in this project. Consequently, several questions were asked concerning the nature and frequency of use of CAL software. Table A.10 shows the frequency of use of CAL in teaching chemistry: this is a total figure for all the staff involved in teaching chemistry in a school - not necessarily for an individual teacher.

Frequency of Use	Number of Schools	Percentage of Schools
Never	58	46.8
Once per year	14	11.3
Once per term	26	21.0
Once per month	22	17.7
Once per week	4	3.2

Table A.10

Use of CAL in Teaching Chemistry

Reason for NOT Using CAL	Number of Teachers	Percentage of Teachers
No suitable material available	13	19
Limited access to computers	9	13
Computers only just arrived	9	13
Unfamiliar with CAL techniques	8	12
No time (to practise etc.)	6	9
No facilities	5	7
Too costly	5	7
Others	13	19

Table A.11

Reasons for Not Using CAL

Those teachers who had never used CAL in teaching chemistry were asked to "....state briefly why you have not used CAL material". While such a question might have been seen as somewhat 'threatening' for the teacher's professional self-image, it produced a range of, apparently honest, responses - summarised in Table A.11.

The percentage figures given in the Table are referred to the 68 'non-users' of CAL who completed this section of the questionnaire. Amongst the 'Others' referred to in Table A.11 were two teachers who said that they were 'unaware of the existence' of CAL and three who said they had 'no interest' in it. The most common complaint in this section - and in informal interviews with teachers - was the 'lack of suitable material'. While there was, undoubtedly, a shortage of software, it must be recognised that 'lack of material' also provides an excellent reason (or excuse) for inaction.

The next section of the questionnaire was concerned with the use of CAL in teaching chemistry. Table A.12 shows the sources of the software available in the schools and Table A.13 shows the number of programs used.

The high figures for the 'Chelsea Science' and 'Schools Council' material can be seen as reflecting the early lead given in the use of CAL in school by these projects. The 'Fiveways' material was published only a short time before the survey and, with the end of the financial year approaching, it was to be expected that few schools would have used this material. Again, at the time of the survey, Longman's had published only one chemistry package and this could be one reason for only a small number of schools using their software. Perhaps the most surprising result was the lack of use of the MUSE software library: whether this was because of the relatively small number of chemistry programs in the library or because the programs were of poor quality or poorly advertised is uncertain. Programs from 'other sources' were principally obtained from teachers in 'other' schools. Taking this figure, together with the number of 'programs by members of staff', clearly shows that the majority of programs in use in schools were, in fact, developed by local teachers. Interviews with teachers and observation of CAL in the classroom would suggest that the majority of these programs are undocumented and circulate primarily amongst teachers experienced in the use of CAL.

Source of Software	Number of Schools	Percentage of Schools
Chelsea Science Simulation Project	21	27
Schools Council Project Computers in the Curriculum	34	43
Longman's Micro Software	7	9
Five Ways Software	0	0
MUSE Software Library	0	0
Programs by Members of Staff	30	38
Other Sources	16	20

Table A.12

Sources of Software

The number of programs actually used in teaching chemistry in the schools is given in Table A.13.

Number of Programs	Number of Schools	Percentage of Schools
1	6	7.6
2	10	12.7
3- 5	20	25.4
6-10	18	22.8
11-20	6	7.6
21+	3	3.8

Table A.13

Number of Programs Used in Teaching Chemistry

The schools where six or more programs were used formed a subset of those schools where teachers had developed programs themselves: this was seen as a reflection of their interest and commitment. The attitude of the LEAs played an important role in promoting the use of CAL in schools. Four of the 'top' nine schools - in terms of the number of programs used - were from North-East Derbyshire, although this was, numerically, the smallest LEA covered by the survey. This seemed to be related to Derbyshire's early decision to standardise on one make of micro - the Commodore PET - and to encourage its teachers to develop CAL software, by seconding teachers, organising CAL-related courses and meetings, and developing a county software library. Unfortunately, Derbyshire was the only Authority in the region to standardise on the PET and, consequently, the programs developed could not be used in schools outside that Authority.

Table A.14 gives the programs nominated, by the teachers, as being most useful in teaching chemistry.

Program	Number of Teachers	Program	Number of Teachers
Contact (1)	17	Haber (2)	3
Element (1)	9	Ecells (1)	3
Equilib (1)	9	Lateng (1)	3
Decomp (1)	8	Others	22

Table A.14

Programs Found Most Useful by Teachers

(1) = Schools Council Project Computers in the Curriculum

(2) = Chelsea Science Simulation Project

The simulation of the 'Contact' process is unique amongst the programs given in Table A.14: it not only allows the student to investigate the effect of varying conditions on the rate of reaction and the equilibrium, but also allows them to examine the economic implications of their choice of conditions. In discussions, teachers always stressed the usefulness of this section in arriving at the 'real' operating conditions and the enthusiasm it generates in the pupils. This 'real-life' aspect of the simulation would seem to be a major factor in its popularity. Of the twenty-two 'others', almost all were programs developed by the teacher recommending them. There was, apparently, considerable overlap in the topics developed - for example, four teachers had developed programs on symbols and formulae and another four had developed units on atomic structure. This duplication of effort is to be expected in any new, rapidly expanding field, especially where there is no central source of information about available programs.

The teachers were also asked to say which features made their chosen programs more useful than other programs which they used. This produced a wide range of answers, the most common of which are shown in Table A.15.

Important Features of Programs	Number of Teachers
Directly applicable to syllabus	8
Simulates a reaction which cannot be carried out in schools	6
Easy for the pupils to use	5
Allows pupils to investigate mathematically complex work	4
Involves industrial problems	4
Highly interactive	3
Allows use of many more examples than would otherwise be possible	3
Others	14

Table A.15

Features which Make CAL Units Useful

The 'features' given in the table, with the possible exception of the first, are the type of 'benefits' which the program developers generally claim for the use of CAL. While the survey returns may simply be a reflection of these claims, the table may show the priority which the practising teacher attaches to different aspects of program design, with 'direct applicability to the teaching syllabus' as an important feature.

The survey also examined the frequency of use of CAL at different levels in the chemistry departments. The teachers were asked to report the number of occasions in a year on which individual pupils, in each of several groups, would be involved in the use of CAL (Table A.16). As might be expected, the table shows significantly greater use of CAL in the upper school.

Group of Pupils	Number of Schools	Mean Frequency of use of CAL	Standard Deviation
'A'-level	38	4.2	3.6
'O'-level	37	3.5	2.4
C.S.E.	29	3.8	2.3
3rd-year and below	18	2.6	2.3

Table A.16

Frequency of Use of CAL

Virtually all the commercially produced material, available at the time of the survey, had been written for use with examination classes and, consequently, those schools using CAL in the lower school had to rely on local sources for their material. In interviews and discussions with teachers, the point was often made that more material was needed for the lower school. However, this view was not totally supported by the survey. When asked for which group of pupils they would **most** like more software, opinions were almost evenly divided between the groups: sixth form, fourth and fifth forms, and third form and below.

Finally, the teachers were asked for which topic they would most like to see a CAL-unit developed. The returns showed great variety, covering wide areas of the 'O' and 'A'-level chemistry syllabus - mole concept, atomic structure, industrial processes etc. For discussion purposes, these were collated into the six groups shown in Table A.17.

Topic Group	'O'-level	'A'-level
Theoretical Aspects	44	17
Simulations of Industrial Processes	7	4
Simulations of Experiments	2	4

Table A.17

Most Desirable Area of CAL Development

Clearly, most of the teachers completing this section would welcome CAL-units illustrating various theoretical aspects of chemistry. This is not necessarily because these aspects are more difficult to teach: it may simply be a reflection of the theoretical bias of the examination syllabuses. However, an examination of the topics included in the 'theoretical aspects' shows that more than half of the 44 teachers involved requested topics in just three areas: 'atomic structure and bonding' (9), 'writing equations' (8) and 'the mole concept' (7). Presumably, therefore, these are areas perceived by the teachers as 'difficult' to teach - this would seem to be supported by research (Shayer, 1979) - and so may be seen as suitable areas for future CAL development.

APPENDIX TWO

SOURCES OF PROGRAMS QUOTED IN THIS STUDY

Throughout the study, individual programs were referred to by a NAME in upper-case. The following Table shows these NAMEs and the sources of the programs, where applicable.

'NAME'	**Title of Published Unit**	**Source**
BONDING	Bonding	BBC Publications
PERIODICITY	Classification and the Periodic Table	BBC Publications
CONTACT	The Manufacture of Sulphuric Acid	CCCC - Longman
DALCO	DALCO	CCCC - Longman
DECOMP	Rates of Reaction	CCCC - Longman
ELEMENT	The Element Game	CCCC - Longman
ECELLS	Electrochemical Cells	CCCC - Longman
FORMULA	Formula	CCCC - Longman
SYNTH	Organic Synthesis	CCCC - Longman
FERTILIZER	Fertilizer	Derbyshire Software Library
INDUSTRY	Siting the Chemical Industry	Derbyshire Software Library
LENS	n/a	not published
ANIMAL	n/a	not published

CCCC = Chelsea College Computers in the Curriculum Project