Group Work with Multimedia in the Secondary Mathematics Classroom

Brian Hudson

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ABSTRACT

The aim of this study has been to investigate the potential of collaborative learning using multimedia in the mathematics classroom. As part of the study, materials and approaches were developed and trialled in classrooms. These trials were carried out in three secondary schools in the Local Education Authorities of Rotherham, Sheffield and Barnsley. All the pupils involved in the classroom trials were 14 to 15 years old, in Years 9 and 10 of the National Curriculum.

A case study approach was adopted and the study itself was divided into three major cycles. In Cycles 1 and 2 the focus of the development was on the integration of the use of the *Domesday* Interactive Video system, within a thematic approach involving practical activity, investigation, problem solving and small group collaboration. The chosen theme was that of *Trees*. The focus of development in Cycle 3 was the multimedia package entitled *World of Number*, which was sponsored by the National Curriculum Council. These resources were available on both laser disc and also CD ROM, with both versions being utilised in the classroom trials.

Prior to Cycle 3 classroom trials the *World of Number* package was evaluated. This involved an initial evaluation by the researcher as an individual user, classroom observation of its use in school, interviews with classroom teachers and also a review of associated literature relating to evaluations and classroom use. The focus of the Cycle 3 classroom trials was on the multimedia-based activities involving one of the units from the package. This unit is based upon the analysis of video clips of motion from the real world using graphs involving speed, distance, height and time.

The findings of this study have highlighted the potential of the use of multimedia in motivating pupils' interest and in promoting collaborative learning. The role of the system has been that of a medium for communication. As the study has developed the theoretical perspective offered by Vygotsky's cultural psychology has come to be increasingly relevant. Attention has been repeatedly drawn to the crucial importance of the role of the teacher and the notion of the *orchestrating* teacher has been seen to be resonant. The need for the provision of *scaffolding* by the teacher and also the need to integrate and coordinate multimedia-based activities with those of the wider classroom context has been emphasised. A micro-analysis of the discourse involved in the multimedia-based activities was carried out which revealed differences in terms of patterns of interaction. There was evidence of varying levels of collaboration and some quite superficial interaction. The importance of the role of the teacher in monitoring the peer interaction and in intervening where necessary has also been highlighted. By examining the development of pupil understanding, the analysis served to illuminate Vygotsky's notion of the function of *egocentric* speech and thus the direction of the development of thinking from the social to the individual, which is central to a socio-cultural perspective.

The study concludes with a consideration of the implications for the design of future multimedia resources, their mode of use, the role of the teacher and also the process of evaluation. Consideration is also given to possible further research questions and also to further related development.

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CHAPTER 1

1.0.0 INTRODUCTION

1.1.0 AIM OF THE STUDY

The focus of this study has been the investigation of the potential of collaborative learning using multimedia in the mathematics classroom.

The classroom trials were carried out in three 11 to 16 secondary comprehensive schools in the South Yorkshire region between the autumn term of 1988 and the spring term of 1994. The study consisted of three cycles, with the focus of the classroom trials in the first two being the use of the *Domesday* interactive video system and that in the third being the *World of Number* mutlimedia package, which was sponsored by the National Curriculum Council. Cycles 1 and 2 involved classroom trials in two schools in Rotherham and Sheffield LEAs and the third involved a school in Barnsley LEA.

1.2.0 OBJECTIVES

The initial objectives of the study were as follows:

1. To identify the major claims of researchers arguing for such a collaborative learning approach by means of a review of up to date relevant literature.
2. To review and evaluate current practice involving the use of Interactive Video and to determine the extent to which collaborative group work takes place.
3. To develop classroom materials and approaches to facilitate the further development of collaborative group work.
4. To evaluate the use of these materials and approaches and to point towards future directions.

The first objective led to the development of the conceptual background of the study. The scope of the second objective was widened considerably to involve a review and evaluation of current practice involving the use of work takes place in a sample of schools throughout the UK which had participated in the Interactive Video in Schools Project. The third objective involved the integration of the use of interactive video in the form of the BBC *Domesday* system in a range of activities linked to a particular theme. The fourth objective led to the further development of the study.

1.3.0 ACTION PLAN

The plan of work for the research was initially devised to be in five phases, the timings of which were subject to ongoing revision especially in the early stages of the study.

Phase 1 involved the planning and preparation of the proposal together with the development of a bibliography relevant to the chosen area of study. Consultations took place during this period with those who had an interest in the field of collaborative learning and a comprehensive search of relevant publications was carried out. The process of identifying suitable schools in which to carry out the research was started and initial contacts made.

A review of the relevant literature relating to collaborative learning and small group work was undertaken in Phase 2. The major claims of writers and researchers arguing for such an approach were identified. These formed the basis of the continuing development of the conceptual background. Consultations were undertaken with regard to classroom practice and relevant activities from other curricular areas, especially with the Centre for Global Education at the University of York. The latter was approached as a result of close working relations and also as a result of the expertise of the staff in relation to collaborative and experiential learning. Initial visits were made to the school to be involved in the Cycle 1 of the study.

A review of relevant literature relating to research methodology with an emphasis upon classroom observation was carried out in Phase 3 which proved to be an ongoing process. Consultations took place with those who had proven experience in the field of educational research within the

University. The methods of data collection were decided upon and appropriate materials to facilitate this process were drawn up.
Phase 4 involved the fieldwork to be carried out in the two schools with pupils in the 11 to 16 age range. It was intended that these schools would have some commitment to collaborative group work and the use of Interactive Video. This phase was be divided into two cycles and proved to be quite an extended period of time from that first envisaged. The purpose of the first cycle was to trial classroom materials and approaches and to collect relevant feedback from pupils and teachers in addition to that from classroom observation. The results of this process were intended to form the basis of the further development in the second cycle. During this period materials and approaches would be further developed, trialled and evaluated. Information was collected by means of classroom observation including the use of video, audio tape and also written feedback from both pupils and teachers for further analysis and evaluation.

During Phase 5 refinement of classroom materials was to be undertaken together with the writing of the thesis. Also consideration was to be given to the dissemination of the study's findings in the form of articles, seminars etc. Publishers were to be approached with a view to the publication of the resulting classroom materials. In fact the process of dissemination was started with an article in Mathematics in School (Hudson, 1990), entitled *Interactive Video in the Mathematics Classroom.* The classroom materials were subsequently published as part of *Century Maths* (see Buxton, Hudson, Gillespie, Miln, Eyles and Singh (1991); Hudson and Gillespie (1991) and Century Maths (1991)).

1.4.0 EXTENDING THE STUDY

Subsequently the study was extended, the objectives revised and a further plan of action was drawn up.

1.4.1 REVISED OBJECTIVES

The revised objectives were as follows:

learning and the use of multimedia.

2. To focus upon the extent to which collaboration is evident in the effective use of multimedia.
3. To investigate the most effective role for the teacher.
4. To consider the most appropriate teaching and learning styles for the effective use of multimedia.
5. To evaluate the design and delivery of the NCC *World of Number* multimedia package in the light of the above objectives.

The first objective contributed to the further development of the conceptual background of the study. The second objective was addressed by means of the Cycle 3 classroom trials, as was the final objective relating to the evaluation of the NCC *World of Number* multimedia package. The objectives relating to the role of the teacher, and teaching and learning styles in general, were addressed partially through classroom trials but also through the development of a theoretical perspective for teaching and learning, which has been incorporated into the conceptual background.

1.4.2 REVISED ACTION PLAN

The National Curriculum Council videodiscs entitled *The World of Number* had only recently become available to schools at the time of Cycle 3 classroom trials. They were also just available on CD ROM and were consequently the focus of considerable interest at a national level. As a result it was decided to focus Cycle 3 classroom trials on the use of these multimedia materials.

In focussing upon the role of the teacher and also upon the underlying teaching and learning styles, it was intended that consideration would be given to the pedagogical issues underlying the use of multimedia. It was thought that this would be especially relevant to the evaluation of the design and delivery of the most recent teaching packages available. In the event this led to the development of a theoretical perspective of much wider relevance, but certainly of particular relevance to this study.

This phase of the study was envisaged to be concerned with the planning would be a further period of reconnaissance and also a period for evaluation of the software in advance of the classroom trials. The final stage of this phase would also involve the analysis and interpretation of the results of the study as a whole and the writing up of the final report.

1.5.0 STRUCTURE OF THE THESIS

The structure of this thesis was influenced by Elliot (1991) and Stenhouse (1975) in their discussion about the reporting of case studies. The latter distinguished between case study, case record and case data. These ideas were expanded upon by Elliott (1991) who described the case data as consisting of all the evidence one collects, e.g. in the form of recordings, transcripts, diaries, notes, photographs, etc. The case record consists of an ordered selection of evidence from the case data, which is organised in terms of its relevance to the issues addressed in the case study. The case study is essentially an analysis of one's experience to date and at points the analysis should be cross-referenced to the evidence on which it is based i.e. the primary sources. This structure is most consistent with my chosen research methodology, it is therefore the one on which the structure of this thesis is based.

The first eleven chapters make up the case study itself, but include some elements of the case record i.e. an ordered selection of the evidence from the case data. The latter is entirely contained within the appendices. The major discussion relating to the analysis and interpretation of the data for the study as a whole is discussed in chapter 10. The conclusions, reflections and implications arising form the focus for chapter 11. However, as outlined in chapter 3, the cycle of action research has been adopted as one of the methods of enquiry. This involves a cycle of planning, action, observation and reflection. Accordingly, there is an element of ongoing reflection throughout the development of this study and therefore, aspects of data analysis and interpretation permeate chapters 4 to 9. The issues raised in this ongoing way are, however, returned to and discussed more fully in the context of the study as a whole in chapter 11.

2.0.0 BACKGROUND TO THE STUDY AND LITERATURE REVIEW

2.1.0 STRUCTURE

This overview draws on a number of strands of relevant literature in setting the conceptual background. These relate to research on:

- collaborative learning in general
- collaborative learning in mathematics education
- collaborative learning in relation to the use of computers.
- the use of multimedia in mathematics

These categories are of course not mutually exclusive with some of the most significant and relevant literature being directly related to the use of computers in mathematics education. Finally particular attention is given to literature relating to theoretical perspectives on learning.

2.2.0 COLLABORATIVE LEARNING IN GENERAL

Interest in collaborative group work developed particularly from my involvement in the use of the computer in the secondary mathematics classroom. This provided first hand experience of the need to organise the classes into groups in order to make use of the limited resources available. This led to the need to capitalise upon what was, in fact, an organisational necessity and it was subsequently found that this thinking coincided with that of Eraut and Hoyles (1989), who noted that the scarcity of computers is likely to make working in groups a practical necessity for many years ahead and hence that it is important to learn how to exploit rather than ignore the potential for collaborative working in groups.

This interest was consistent with other trends within the educational system at that time. For example the Cockcroft Committee in 1982 called for an increased emphasis upon discussion in the mathematics classroom between both teachers and pupils and between pupils themselves. The developments arising from the Cockcroft Report in this respect were reinforced by the introduction of GCSE during this period. A further significant influence at this time came from developments in vocational education and from the

TVEI initiatives in particular which placed emphasis upon active learning involving pupils working in groups.

2.2.1 RESEARCH CULTURES

During the course of this study it has become evident that there are a number of clearly distinguishable research cultures when one considers collaborative group work. Some researchers distinguish between *co-operative* and *collaborative* working with the former in the main emerging from the American research community and the latter from the British. However a number of British researchers such as Bennett and Dunne (1989) and Cowie and Ruddock (1988) do refer to *co-operative* group work. In reporting the findings of the ORACLE study, Yeomans (1983) refers to *collaborative* learning but distinguishes between American research into *co-operative* group work and British research into *collaborative* group work. In general the American research has differed from the British in terms of methodology as well as in the nature of what is defined as group work. In terms of methodology it has attempted to be more scientific with the use of control groups being far more common. This is in contrast to the British research in this field which has consisted largely of descriptions of case studies. In terms of the nature of activity, the co-operative learning methods of the American research community are based upon the social-psychological theories of Deutsch (1949) which stress the motivational effects of the co-operative task setting as the main focus for interpreting the social and academic benefits.

In contrast the British research is based within the peer collaboration paradigm which attempts a more cognitive analysis of group interactions using theoretical frameworks from developmental and social psychology. In this model the role of language has been a prominent feature and socio-cognitive conflict and negotiation of joint action are two mechanisms by which social interaction is seen to lead to effects on individuals' cognitive functioning. Eraut and Hoyles (1989) analyse the influences further and their work will be considered more fully later in this chapter.

Teasley and Rochelle (1993) make the distinction between *collaborative* and *co-operative* problem solving. The former involves the mutual engagement of all in a coordinated effort to solve the problem together, whilst the latter is seen to be accomplished by the division of labour among participants, where each member is responsible for a portion of the problem solving.

The major influence at the start of this study was that related to co-operative group work associated with the American research community. This was the major element of the initial background and literature review prior to the Cycle 1 classroom trials.

2.2.2 AMERICAN RESEARCH INTO CO-OPERATIVE LEARNING

The starting point of this review was to examine the relevance of research on co-operative learning and to consider the claims of its advocates. The initial stage of this review was related to the work of Johnson et al (1984) in particular.

One of the earliest advocates of co-operative learning was Colonel Francis Parker who was superintendent of the public schools in Quincy, Massechusetts from 1875 to 1880. John Dewey followed Parker in promoting the use of cooperative learning groups as part of his project method of instruction. Deutsch (1949), building on the theory of Kurt Lewin, proposed a theory of co-operative and competitive situations on which the subsequent research of Johnson et al (1984) was founded.

Significant claims are made by the advocates of co-operative learning with regard to levels of achievement. Johnson, Maruyama, Nelson and Skon (1981) report on an analysis of all the studies that had been conducted on social interdependence and achievement. They reviewed 122 studies carried out between 1924 and 1981. Their analysis indicated that co-operative learning experiences tend to promote higher achievement. These results were claimed to hold for all age levels, all subject areas and for tasks involving concept attainment, verbal problem solving, retention and decoding and correcting tasks, it was found that co-operation is as effective as competitive and individualistic learning.

Johnson et al (1984) conducted an extensive investigation of why co-operation should be more effective in promoting achievement than competitive, individualistic or traditional methods. This research aimed to identify the factors contributing to the effectiveness of cooperative learning. They reported that the type of learning task does not seem to be an important factor. They found that the discussion process in co-operative learning groups promotes the discovery and development of higher quality cognitive strategies for learning. They observed that active participation in co-operative learning groups produces conflicts among ideas, opinions, conclusions, theories and knowledge of members. It is argued that, when managed skilfully, such conflict promotes increased motivation, higher achievement, more retention and greater depth of understanding. Johnson et al report that discussion among students within co-operative learning situations promotes more frequent oral repetition of information; the stating of new information; and explaining, integrating and providing rationales. Further, within co-operative learning groups, there tends to be considerable peer regulation, feedback, support and encouragement of learning. They argue that the exchange of ideas among students from a variety of ability levels and from different ethnic backgrounds enriches their learning experiences, and that co-operative learning seems to be enriched by heterogenity among group members. They also report that the liking students develop for each other, when they work collaboratively, tends to increase motivation to learn and to encourage each other to achieve.

Enhancement in levels of critical thinking, more positive attitudes towards subject areas and improvements in the ability to work collaboratively are reported by Johnson et al. The industrial strategy of Japan is illustrated as an example of the principle of preparing students for careers and adult responsibilities. Japanese management is reported as claiming that the superiority of the Japanese industrial system is based upon the fact that their workers are better able to work in harmony and cooperation with each together in co-operative learning groups master collaborative competences at a higher level than do students studying competitively or individualistically. Their studies also indicate that co-operativeness is positively related to a number of indices of psychological health, namely: emotional maturity, well-adjusted social relations, strong personal identity and basic trust in and optimism about people. They show further that competitiveness also seems to be related to a number of indices of psychological health, while individualistic attitudes tend to be related to a number of indices of psychological pathology, emotional immaturity, social maladjustment, delinquency, self-alienation and self-rejection. To the degree that schools can contribute to a student's well-being, it is argued that schools should be organised so as to encourage those traits and tendencies that promote it.

A number of findings concern relationships with others and also self image. For example, it was found that co-operative learning experiences promote considerably more liking among students for one another regardless of differences in ability, sex, disability, ethnic origin and social class. Co-operative learning experiences have been reported to result in stronger beliefs that one is personally liked, supported and accepted by other students and to promote higher levels of self esteem in general. In fact it was found that co-operative learning experiences serve to break down stereotypical views of others and tend to promote expectations towards more rewarding and enjoyable future interaction among students.

A further finding was that cooperative learning experiences also affect relationships with adults in school. Students participating in co-operative learning experiences are reported as liking the teacher better and as perceiving the teacher as being more supportive and accepting academically and personally.

Johnson et al define interaction as promotive or oppositional and report that, within co-operative learning situations, students benefit from helping each other to learn, while in competitive situations they benefit from obstructing success or failure of others is irrelevant.

They identify four basic elements as being essential in structuring co-operative learning:

- positive interdependence
- face-to-face interaction
- individual accountability
- interpersonal and small group skills

The achievement of positive interdependence may be gained through mutual goals (goal interdependence), divisions of labour (task interdependence), dividing materials, resources or information among group members (resource interdependence) and the giving of joint rewards (reward interdependence).

They also note that students need to perceive such interdependence in order that co-operative learning takes place. It is the interaction patterns and verbal interchange among students, promoted by positive interdependence, that affect educational outcomes. They argue that students need to be taught the social skills required for collaboration and be motivated to use them. Further, they also need to be given time and procedures for analysing how well their learning groups are functioning.

2.2.3 AMERICAN MODELS OF GROUP WORK

Yeomans (1983) reports on the development of co-operative group work which has taken place in the USA since the 1970s, which has focussed on a number of distinctive methods. Those which have been most extensively developed and evaluated are Student Team Learning /Peer-Tutoring and Group Investigation. The former method encourages competition between groups, whilst the latter is based upon co-operation and is much closer to the British tradition.

Peer-Tutoring, as thus defined, aims to foster peer cooperation by creating interdependence within groups through a jig-saw technique involving subdivided, with each member learning her own subtask by forming a counterpart with members of other groups working on an identical task. These students then return to their original groups and present what they have learned. All students must learn the parts of the main task by being tutored by peers. Rewards are given to the winning group, and competition is encouraged by placing the groups into leagues and divisions.

The second major distinctive area of American research relates to the method of Group Investigation. This is defined as learning through co-operative group inquiry and discussion which is much closer to the British model of collaborative group work than Peer-Tutoring. Group Investigation involves data being gathered by the group as a whole. This is then interpreted and individual contributions are synthesised into a joint product.

2.2.4 CRITIQUE OF AMERICAN RESEARCH

Researchers have raised questions about the validity of some of the claims made by the advocates of co-operative group work. For example Yeomans (1983) raises the question of whether certain subjects are more appropriate for this type of learning following results from Peer-Tutoring in a range of subjects with apparently different levels of effectiveness. A further question which is raised is whether the improved results depend upon team reward rather than co-operation. Yeomans notes that the team score is obtained by adding together the scores obtained by individual members in matches against opponents of similar ability, thus creating reward interdependence. The peer-tutoring techniques used retain many fundamental features of traditional whole class instruction i.e. acquisition of basic information and skills through teacher presentation of learning materials, accountability through testing, and little or no open discussion of ideas.

Yeomans also draws attention to certain weaknesses in some of the research on academic achievement and social and personal development conducted by Sharan, Lazarowitz and Reiner (1978). In this study the effects of group work on academic achievement and social and personal development were two year project to train them in group work skills and to implement these in their teaching. Collaborative group work was used for a year in these schools prior to a three week experiment in which pupils from these schools were compared with pupils from a similar nearby school, who had been taught by traditional whole class methods. Gains were reported in terms of academic achievement, and also in terms of social and personal development, in the trial schools when compared with the control group.

In a critical appraisal of the study Yeomans observes that the actual experiments lasted a mere three weeks and involved a total of 217 pupils, all from a poor neighbourhood. However the children in the experimental group had been taught by teachers undergoing a two year in-service programme, which was an experience not shared by teachers in the control school. Furthermore, the experimental group had been engaged in collaborative group work for a year prior to the experiment, whilst the pupils in the control group had received no special attention during this time. She raises the question of the validity of the control group and notes that it is impossible to separate the effects of two crucial variables, that of the in-service programme and that of the group work programme. Essential factors such as teacher motivation and commitment and their effects on pupil performance were also ignored.

Apart from these criticisms Yeomans finds the evidence for many of the claims of the American researchers to be valid. These indicate that cooperative group work based on the Group Investigation model is more effective than either traditional class teaching or competitive group work, using peer-tutoring based upon rewards, for both academic achievement and social development. She notes that the evidence supports the hypothesis that collaborative group work is particularly suitable for learning tasks involving complex, high level cognitive processes.

2.2.5 BRITISH RESEARCH ON COLLABORATIVE LEARNING

Both Plowden (1967) and Bullock (1975) suggested group discussion as a means of improving learning and many of the studies in British schools have focussed on the role of language in collaborative group work. Barnes, Britton and Rosen (1969) highlight the importance of language for learning and advocate the use of small groups for exploratory talk. Subsequent research by Barnes and Todd (1977) led them to conclude that pupils gain a great deal from working in collaborative groups.

In addition to an emphasis on language, many British researchers have focussed far more on the process of learning than on the measurable outcomes typical of the American research. Cowie and Ruddock (1988) focussed upon how pupils in co-operative groups begin to explore and negotiate their meanings through dialogue, active participation and engagement in issues of personal significance. Using classroom observation of pupils working in groups together with interview techniques they have made qualitative analyses of the processes at work when pupils learn co-operatively from one another. The findings from this study confirm those from the American studies.

Cowie (1988) notes the strong personal and organisational barriers which operate against the widespread use of co-operative learning in school contexts, and refers to the deeply embedded idea that academic learning is an individual activity. She observes that even teachers who talk about the benefits of group work will often betray their doubts by saying how time consuming it is and how difficult it is to get through the examination syllabus in any other way than the traditional didactic mode. Cowie notes further that the unspoken but implied view seems to be that, however worthy it is for students to become articulate, critical and analytical, the real task of the teacher is to prepare students to succeed in a competitive examination system.

It is further noted that where there is a strong tradition of didactic instructional methods, individual teachers find it hard to introduce new ways of working such as co-operative learning. The need for in-service training and support for groups of teachers who can work together to initiate change is noted. Cowie and Ruddock (1988) argue that what appears to be missing is a common language within schools and across schools for organising and valuing group work. In their view decisions need to be made at the level of school policy for building a common framework of understanding and practice, which will clearly legitimise group work in the eyes of pupils and parents. They suggest that school policy should ensure that teachers have opportunities to discuss their different perspectives and experiences and to build common ground through such dialogue.

Writing about the findings of the ORACLE study, Yeomans (1983) found that such barriers to collaborative group work were widespread, with evidence of its occurrence being very thin. What teachers commonly described as group work was in fact most frequently simply an organisational arrangement with pupils sitting together as a group whilst working on individual tasks. These were also the findings of Bennett et al (1984). Bennett and Dunne (1989) reporting on the research of Bennett and Cass (1988) find that this was generally supportive of the claims made by the American researchers. They observe that it was apparent that where a demand for co-operation was made by the teacher, co-operative endeavour and on-task behaviour increased to a high level. They also established that there was a relationship between interaction in the group and pupils' understandings of the task. They note further that whilst finding support for the claims made for co-operative learning, most studies provide no information on issues of classroom implementation nor on the critical role of the teacher.

2.3.0 COLLABORATIVE LEARNING IN MATHEMATICS EDUCATION

A major British contribution to research in the field of mathematics education has come from Hoyles et al. Writing in 1985, Hoyles points to the mounting evidence of the inadequacies of traditional school mathematics and calls upon mathematics educators to turn their attention to collaborative modes of learning. The focus is upon language and group discussion and support for this view is found in the report of the Cockcroft Committee (1982) which noted that language plays an essential part in the formation and expression of mathematical ideas and suggested that school children should be encouraged to discuss and explain the mathematics which they

Davidson (1985) provides a selective but comprehensive overview of small group learning in mathematics. He notes that claims for gains in levels of achievement have been made mainly with reference to computational skills, simple concepts and simple application problems. Thus the claims for the benefits for co-operative group work should be qualified by the narrow range of dependent measures that has been examined. In their review of the literature, which draws heavily on the American research community, Good, Mulryan and McCaslin (1992) agree that research supports the increased use of group work but that it is important to recognise the "diverse conceptualisations of *co-operation*". They argue that some forms of co-operative learning are more important than others but that an important issue is the "quality of planning and instruction".

Writing about group work with computers Eraut and Hoyles (1989) point towards the significant body of research on group work in classrooms where no computer is present and comment on the very limited amount of research that has been carried out related to computer use. They note that in addition to this important practical reason for learning more about group work with computers, there are compelling theoretical reasons for believing that group work has considerable potential for the enhancement of learning. They argue that it may not be just a question of showing that learning in groups can be as effective as individual learning but that there are learning goals and tasks for which psychologists believe that group work is likely to be more effective. In their review of relevant research they identify at least three types of argument for having groups in classrooms. The first of these is based upon the role of group interaction in the enhancement of learning, the second on the positive social effects of working in groups, and the third on groups as a mode of class organisation which allows some differentiation of task and a distinctive form of teacher control.

They also identify three main sources for arguments for group interaction. The oldest of these is attributed to psychologists and educators who stress the role of language in learning, particularly spoken language. Language is seen in this paradigm, not merely as a way of communicating existing meaning, but as the means by which meanings are created. This view is traced back to Hegel and more recently to the psychologist Vygotsky (1962), who regarded speech as an important means of guiding action and interpreting the world. Much of the British research can be seen to follow in this tradition and this perspective has come to be of increasing significance to my research project.

The second main source of argument for group interaction is identified as being related to oral language but giving primacy to the need for co-operative orientation among learners. This line is traced back to Deutsch (1949) and Bruner (1966) on which much of the American research is based.

The third main source stems from the arguments of a group of Genevan developmental psychologists based upon a Piagetian theory of learning. In socio-cognitive developmental theory, Doise and Mugny (1984) introduce the concept of group cognition. They argue that children must work in groups to facilitate the breakdown of individual/egocentric understanding without being presented with a didactically induced demand for an answer. This theory is resonant with recommendations in mathematics concerned with the child's development of thought between the "embedded" and the "disembedded" as outlined by Hughes (1986). Others within this tradition see group work as a mechanism for providing cognitive conflict and thus for promoting cognitive enhancement or advancement in stage development. These arguments are attributed to Perret-Clermont (1980) and Bearison, Magzamen and Filardo (1986). Essentially cognitive conflict arising from differences in subjects' approaches to or perspectives on a task is seen as the key to development.

Hoyles (1985) considers group discussion in mathematics and the role of conflict in this form of learning. In considering Bruner's (1962) description of reciprocal learning Hoyles notes that he suggests that even while one participant is talking, she will be receiving information from her partner which leads her to reshape what she is saying while she is actually saying it. Whilst in the process of finding a verbal form for her thoughts, it is argued that the listener will modify them as a result of signals from the talker. It is further argued that it is this immediacy of feedback, taking place at the moment of choice, which facilitates the internalisation of another's point of view. An alternative articulation of this process is offered by Hoyles to the effect that it is the interactions between the constructions of meaning by the speaker, their reconstructions by the listener, and the contradictions that can arise, which can generate increased understanding.

Hoyles also suggests that conflict within a discussion can arise merely in the process of communication of an idea. Further, she draws attention to early Piagetian work where social co-operation and conflict were cited as prime instigators of development. She argues further that language facilitates reflection and internal regulation since difficulties in formulating the language to describe a situation may lead the speaker to modify her analysis of that situation. Attention is drawn to the importance of the role of the teacher in the learning process in order to encourage reflection on what has been done and on what further outcomes could arise.

Pozzi, Healey and Hoyles (1993), reporting on studies of social interaction in the context of mathematics learning, suggest that socio-cognitive conflict represents only one of a number of mechanisms underlying individual learning gains. These findings also point more towards the Vygotskian idea of co-construction, rather than conflict, as a mechanism for cognitive change (Vygotsky, 1962).

Good, Mulryan and McCaslin (1992) also give consideration to the theoretical perspective provided by Vygotsky and reflect their focus upon the American research community in their observation that "most research on student learning has ignored how students think and learn while interacting with peers on a co-operative task".

COLLABORATIVE LEARNING AND COMPUTERS

Most of the work carried out by Hoyles et al has been in the context of the use and development of the programming language Logo. Hoyles and Sutherland (1987) draw attention to the importance of the role of the teacher in setting the classroom atmosphere in which the learning can take place effectively. They comment on the role of teacher intervention and observe that intervening to provide pupils with a rule or an idea has little or no effect until the pupils themselves have seen the need for these ideas. It is claimed that the mere act of copying or being told induces both a focus on the product and a passivity in the pupils which is destructive to learning. Within an atmosphere which encourages active reflection, however, they note that pupils have been able to devise and overcome challenges within their own projects in ways they would not have been able to predict.

Eraut and Hoyles (1989) raise a number of questions which they argue provide a focus for guidance for teachers wishing to gain maximum benefit from the use of computers. These relate to the most appropriate types of learning goal for group work with computers, its potential contribution to the curriculum, how computer- and non-computer-based tasks can be designed which facilitate group work, criteria for task design and group management, group composition, how group work can best be prepared for, implemented and evaluated and whether training in collaborative group work is a significant advantage.

In a review of research, the role of the microcomputer in encouraging discussion and co-operation in the classroom is reported by Govier (1988). It was found by Fletcher (1985) that groups of children performed better than individuals working silently, although silent individuals worked more quickly. In a study of interactive patterns between teachers and pupils and also between pupils themselves, Riel (1989) concludes that computers by themselves do not lead to the restructuring of education, but computer technology in the hands of good teachers can be an extremely effective tool in the education process.

Blaye, Light, Joiner and Sheldon (1991) review research in the developmental psychology and cognitive science literature on peer interaction in the context of computer use. They report on a study in which eleven year old children worked on a problem-solving task, concluding that those who had previously worked in pairs showed a substantial advantage. They argue that their results emphasise the need to consider the interactive context of use of educational software during its design, development and evaluation.

Cummings (1991) suggests that the computer can be an effective motivator in group work and observes that, with the increasing application of IT in the curriculum, teachers' time and energy can be freed for the fuller exercise of pupils' skills in oracy which are so often neglected by over-attention to the written word. He argues that more emphasis should be placed upon the function of language as a shaper of meanings and that the computer has a powerful contribution to make in facilitating this process.

Johnson, Johnson and Stanne (1986) carried out a comparison of computer-assisted cooperative, competitive and individualistic learning with a group of thirteen year old pupils. They report that computer-assisted cooperative instruction promoted greater quantity and quality of daily achievement. Further results include more successful problem solving, more task-related pupil-pupil interaction and an increase in the perceived status of girls.

Hoyles, Healy and Pozzi (1994), in reporting on their analysis of the functioning of groups with computers, point to the importance of task design which prioritises the sharing of task components and the contribution to their synthesis by group members. They also highlight the computer's role as a "flexible aid in constructing mathematics, as a public debugging device and as a support for verbal explanations".

Hoyles et al identify four patterns of interaction and learning and in particular they identified a continuum between a *directed* setting and a *mediated* one. Directed settings were characterised by the domination of one or two pupils. In the directed setting pupils were categorised as either *directing* or *directed*, according to whether they adopted the position or were influenced by it. When no positions emerged and the setting was negotiated all pupils were classified as *mediated.* In their study they distinguish between local and global targets with the former related to computer-based activities and the latter to a wider network of mathematical activities involving discussion and the comparison of alternative perspectives and approaches. When consideration was given to the integrated setting as a whole, two further patterns of interaction emerged i.e. *navigated* and *driven.* In navigated interactions, one or two pupils emerged to take control of the global mathematical issues, while influence on the local targets remained evenly distributed. In driven interactons, the local targets, at the computer, were dominated by one pupil.

Amongst their findings, Hoyles et al report that learning benefits emerged from mediated settings or from "being navigated", with pupils who were driven or directed benefiting least. Pozzi, Healy and Hoyles (1993), writing on the same study, report the finding that there was a high association between pupils who dominated and pupils of high ability. The latter was assessed according to teacher designation or in terms of a high pre-test score.

Pozzi, Hoyles and Healy (1992) report on research studies in which researchers have applied a framework of socio-cognitive conflict to computer-based tasks. They report on evidence of peer facilitation effects when young children worked on computer-based tasks which required joint decision-making. They also report on evidence of pairs who mutually developed their strategies on a problem solving task being more effective than those who had been shown optimal solutions by an adult or who had solved the problem by themselves. This was conditional upon the children involved exhibiting some kind of strategy in their approach to the task as well as upon intervention to prevent either partner from wholly dominating the interaction. They use this evidence to support the findings from their own study. Their findings also lead them towards the Vygotskian idea of co-construction, rather than conflict, as a mechanism for cognitive change.

This leads them to suggest that a scenario for optimal learning with computers is one in which the pupils first engage in mutual discussion with peers in the context of construction with the computer, then encounter the perspectives of other pupils in whole group discussion. They argue that without the former, pupils may not have developed any kind of strategy or understanding of the problem, so cannot make sense of any possibly conflicting strategies from their peers. Without such discussion, pupils are likely to remain fixated on their own way of understanding the problem and so are less likely to learn. The role of the software is seen to be crucial in allowing the pupils to construct the mathematics for themselves at their own level of sophistication.

Hoyles and Noss (1992), in outlining ideas related to a pedagogy for mathematical microworlds, write about their appreciation of the "inescapable and perhaps unpalatable fact that simply by interacting in an environment, children are unlikely to come to appreciate the mathematics which lies behind its pedagogical intent." In particular they argue that whilst students structure their activities by their own actions, these actions are structured by the constraints and design of the activities in which they are engaged. They emphasise their intention for students to have enough time and space to mathematise their own ideas with the computer and, in fact, to "play" with the software. At the same time they emphasise the need for reflection on the mathematical features of the problem or situation and also for pedagogies which can be designed which "scaffold" students' sense making in mathematics.

2.5.0 MULTIMEDIA AND MATHEMATICS

During the course of this study a tension has become apparent with regard to the underlying teaching and learning styles associated with the use of multimedia in the classroom. This has arisen from the expectations of some of the proponents of its use and also from the assumptions of some of the potential users. Such tension is common in relation to the use of computer assisted learning in general and in their evaluation of the IVIS programme Norris, Davis and Beattie (1990) draw attention to the general concern that authority is invested in the machine and that the underlying pedagogy is therefore didactic. This concern has been exacerbated in the United Kingdom as the major proponents of the use of interactive video in schools have been Government Ministers of the political Right who would seem to be in sympathy with such a transmission model of learning. For example the Industry Under-Secretary of State is reported (Education, 9.4.87) as "boasting", on the announcement of the trialling of the IVIS discs, that the Department of Trade and Industry was showing the way in educational innovation and expressed the hope that others, such as the Department for Education and Science, would in due course catch up with this new dawn in learning. The Minister is further reported (Training and Development, 1988) as arguing that this country has lagged behind our American and Japanese counterparts for too long in recognising the need for long term training strategies built on the most advanced methods. He argued for the use of "infinitely flexible" and "highly cost effective" technology to "enhance our productivity and sharpen our competitiveness equipping Britain as a leading player in world markets for the 1990s and beyond". Wade (1988) reported that the Government, primarily in the form of the DTI and the DES, appeared to have "ambitious plans for the development of interactive video in education". He reported on "a putative scheme" from the DES which envisaged the spending of £3 million on the production of video discs for school physics which was seen to be "a part-solution to the chronic scarcity of (physics) teachers." These factor have undoubtedly contributed to a level of distrust on the part of many potential users.

However, Norris et al conclude that for the IVIS programme this was not a major issue in general terms as most of the developers had attempted to devolve control over the teaching and learning processes to the users and that, to varying degrees, they had succeeded. They identify four forms of software through which the user interacts, which are not mutually exclusive. These are a system of classification, a system of fixed branches or routes, presentational tools and a system of rules. They proceed to consider the IVIS science and mathematics discs and categorise both as a system of rules. The mathematics disc is structured around the simulation of the organisation of a school disco in which the students have to work through a menu of decisions on where to hold it, what music to play, which publicity. When all the decisions have been made the students can see the "outcome" of their actions. Within this scenario, interaction is through a non-arbitrary system of rules within a domain of expert knowledge or reconstructed experience. Accordingly control over what is presented and relationships with the video environment are determined by the software, although the user has some freedom to experiment within the confines of the rule system.

This analysis seems to be accepted by Kennett (1989), as leader of the development team for the IVIS mathematics disc, who argues that much IV use in training corresponds to computer aided instruction, in which the system transmits information and tests the learning. Sometimes this is seen as drill and practice and sometimes it is considered as an intelligent programmed learning machine. He suggests that "some would argue" that as exposition is still the main teaching style for large parts of mathematics courses, and the rule-example-practice paradigm is frequently used throughout the mathematics classroom, then IV has a role to play in that it could "do" certain parts of the course. He considers an American example of IV, (*Core Concepts in Action*, Systems Impact Inc., Washington D.C.), being used on the basis of a model of mastery learning and confirms that, in part at least, such a model was used in the design of the mathematics disc; although he also categorises the model as a simulation.

Straker (1987) also considers the same American example of mastery learning and concludes that the IVIS mathematics disc is much less instructional in tone than this model. However he does call for attention to be given to "any learning package which addresses the potentially difficult and often unattractive areas of fractions, decimals and percentages and achieves the successes claimed".

In this context it is pertinent to consider Skemp (1976) who, in his influential paper on instrumental and relational learning in mathematics, attacked the very basis of such a behaviourist model of learning. He highlighted the deficiencies of a hierarchical and mechanistic model of learning by pointing out that, if A, B, C and D are four steps that appear in a learning hierarchy, teaching students to go from A to B, and then from B to C, and then from C to D does not necessarily assist them to acquire a holistic understanding of how A, B, C and D are related. Further there is no guarantee that someone who has learned each individual step could then return from D to A.

Straker, however, does acknowledge that the "true and exciting" potential of the medium will be realised (in the UK) by focussing on real mathematics through practical work, problem solving and investigation. He asserts the need for courseware to be designed for small group use given the practical constraints and calls for careful consideration to be given to classroom organisation. He argues that it may be advantageous to consider a videodisc as part of a much larger materials package. He also predicts the question from teachers of "what do I do with the other 25 pupils?" which he considers must be addressed and in doing so highlights the difficulties associated with individual use of the system.

Atkins and Blissett (1989) report a study of the types of learning activity which took place when groups of pupils were working on the mathematics video discs which resulted from the Interactive Learning Project, based at the University of Newcastle-upon-Tyne. The study took place in the autumn term of 1987 with pupils in the 9 to 13 age range. The researchers identified six types of learning activity:

- discussion related to the task
- reading/watching/listening
- decision entry and recording (by use of the mouse or keyboard or by note taking)
- technical (in relation to negotiating the software/hardware)
- dead time (waiting for the program to respond, printer to print etc)
- off-task social activity

Atkins and Blissett report a number of findings from their study, the first of which was the high proportion of the learning activity which was in the learning but the authors argue that such an interpretation could be naive given that the presentation of information and of explanations can be intellectually challenging, requiring the pupil to process new inputs, establish links to prior knowledge and understanding and to form new conceptual networks. This view is supported by the analysis of Laurillard (1984) who defines this as a *receptive* mode of learning.

They also consider the role of discussion in their study, which accounted for 23% of the learning activity. They observe that the quality of pupil discussion varied from "a trivial and superficial conversation about the problem" to "real engagement with its constraints and possibilities". They argue that, although discussion may take place, and that this "looks like evidence of interaction" it does not of itself guarantee effective learning. Further, they suggest the need to examine the claims for interactivity and to relate them more carefully to work on learning and learning styles.

A further finding is the major variations within groups in the proportion of time spent on the various learning activities from one session to another; e.g. one group spent 29% of the time on discussion in the first session, 15% in the second and returned to 25% in the third, whilst the pattern of another group was almost the reverse. They point to the difficulties of interpreting group learning processes and also to the need for the dynamics of such group processes to be taken into account by software designers "if their discs are to be used by small groups on a virtually stand-alone basis".

This latter conclusion raises a question about the role of the videodisc system in relation to that of the teacher. In a further study in 1992, Atkins and Blisset investigated the deployment and development of cognitive-problem solving skills in relation to code cracking problem, which was a part of a video disc package. In this study, the intervention of the teacher proved to be crucial for effective learning to take place. They argue that a human tutor who can respond individually and dynamically is essential for learning optimal problem-solving skills and for the deployment of a relevant repertoire of strategies. However, they still consider a possible

The role of the teacher is discussed by Norris, Davis and Beattie (1990), who cite a report from the United States Office of Technological Assessment, which concluded that educators and educational researchers consistently identify the role of the classroom teacher as being the one factor central to the full development of the technology's use in schools. Norris et al consider that these findings were reflected in those of the IVIS project which demonstrated that the educational value of IV lies in the area of teaching support. In general the IVIS teachers considered that IV could be a useful resource, capable of being adapted to teachers' own requirements and styles of work.

Many of these findings are echoed by Wright (1988) when considering the role of the *Domesday* interactive video system in the mathematics classroom. He concludes that "students using IV often work in small groups with a great deal of discussion in evidence". He also comments on the role of the teacher and describes a model of the classroom which does not see the teacher as simply a provider of knowledge but also as a "classroom manager, student consultant and motivator".

2.6.0 THE DEVELOPMENT OF THEORETICAL PERSPECTIVES ON LEARNING

2.6.1 RADICAL AND SOCIAL CONSTRUCTIVISM

The underlying philosophy which was brought to this study involved a commitment to an investigative approach consisting of collaboration, problem solving, practical work and discussion. Further significant aspects of this approach included a commitment to active learning, the flexible use of resources and the application of mathematics in real social and cultural contexts. This philosophy could be broadly described as constructivist. My own understanding of this philosophy has developed significantly, over the course of this study, as the pedagogy of the research community in mathematics education itself has developed over recent years.

outlined radical constructivism. The two principles underlying a radical constructivist view of learning and knowledge are that firstly knowledge is actively constructed by the cognising subject rather than being passively received from the environment. Secondly, coming to know is seen to be an adaptive process that organises one's experience of the world rather than discovering an independent, pre-existing world outside the mind of the knower. Learners are not seen to discover some absolute form of knowledge which exists outside of themselves but rather they learn by adapting what they know to fit with what they experience. Individual's understandings are seen to be built from their own unique web of prior concepts and as such are idiosyncratic.

As Schifter and Simon (1992) point out, it is inconsistent with such a view to think that teachers can "implant bits of their own web of understandings into their students' heads." At any given time an individual's understandings are seen to be organised as a network of existing knowledge and the construction of new understandings is stimulated when a situation is encountered that challenges the individual's current organisation of knowledge. This challenge can be seen as a disturbance or disequilibrium which leads to mental activity and the modification of previous conceptual structures.

The importance of reflection in this process is emphasised by von Glaserfeld (1987) who states it requires effort, in fact, "a succession of reflective efforts" given the levels of abstraction involved in mathematical thinking and it is contended that such effort can only arise from a strong sense of inner self motivation.

Jaworksi (1994) emphasises the importance of the social nature of learning through communication with others in outlining a social constructivist perspective. When discussion takes place images and perceptions are shared and meanings are negotiated which may lead to some consensus in terms of beliefs and understandings. Social constructivism is seen to be concerned with the shared meanings within a community and historically the growth of mathematical knowledge can be seen as the development of shared meanings within the international mathematical community. The negotiation of meanings within a group can be the source of cognitive conflict leading to disturbance or disequilibrium, mental activity and internal reorganisation of conceptual structures.

2.6.2 CO-CONSTRUCTION/SOCIO-CULTURAL THEORY

It can be seen that such a theoretical perspective is consistent with the starting point of much of the research previously reviewed in this chapter. However, research carried out in relation to collaborative learning in mathematics education has resulted in questions being raised about the adequacy of this perspective when considering a social and communicative model of learning (e.g Pozzi, Healey and Hoyles , 1993). Good, Mulryan and McCaslin (1992) draw attention to the theoretical perspective provided by Vygotsky as an area which has been neglected by researchers, in America at least. Pozzi, Healy and Hoyles (1993), in reporting upon their work in the context of group work with computers, also indicate that this has led them towards the Vygotskian idea of co-construction, rather than conflict, as a mechanism for cognitive change. This is paralleled by developments within the mathematics education research community in general. Given an increasing interest in interaction within the mathematics classroom in recent years, some researchers have begun to question the adequacy of such theoretical perspectives as radical and social constructivism in particular. For example, Lerman (1993) argues that radical constructivism is severely limited in that "it ignores so many aspects of social life and all of the power of communication, language and enculturation" and argues further that social constructivism is "incoherent and inconsistent". He also points towards a socio-cultural view of learning based, in part at least, upon Vygotsky's cultural psychology.

From such a perspective, individual structures are seen to be formed by social interaction, with development reflecting a move from the interpsychological to the intrapsychological. This has been described as co-construction or socio-cultural theory and is based upon a communicative, culturally orientated conception of learning. Within this framework this theory is the "zone of proximal development" - the distance between the actual developmental level as determined by independent problem solving and the level of potential problem solving under adult guidance or in collaboration with more capable peers. A Vygotskian approach also supports the notion of an optimal size for the "cognitive distance" between pupils within a group as it points to the importance of establishing some initial mutual understanding as well as maintaining and developing this understanding during communication. It also leads to the idea of "scaffolding" the learning task, which Bruner (1985) developed from the work of Vygotsky. This serves to highlight the critical function of the tutor in structuring the learning activities and enabling the learner to internalise external knowledge.

The empirical findings of my research study also point in the direction of the development of such a perspective and thus serve to highlight the one strand of this study which seems to lack any clearly articulated theoretical perspective underlying its development - namely the area of multimedia and mathematics. This particular field seems to display tensions, misunderstandings and confusion on all sides about the part played by the technology and no strongly articulated model for teaching and learning is in evidence from developments to date.

Given this background the work of the following researchers is particularly relevant. Forman and Cazden (1985) consider the value of peer interaction from a Vygotskian perspective, whilst Jones and Mercer (1993) and Laurillard (1993) both consider the role of the computer in learning from such a perspective also.

Forman and Cazden (1985) comment that "when we try to explore Vygotskian perspectives for education, we immediately confront questions about the role of the student peer group". They trace the theory of Perret-Clermont (1980) relating to the importance of cognitive conflict back to Piaget's theory concerning the role of social factors in development. Further they argue that when Piaget looked at peer interaction it was for interested in describing or explaining social interactional processes as a whole. They continue by observing that in situations where overt conflict is not apparent and where mutual guidance and support are evident, his theory provides few clues concerning the role of social factors in development. It is in the area of adult-child interaction that Vygotsky offers insights into the intellectual value of these kinds of peer interaction.

Forman and Cazden also note that Vygotsky uses the notion of internalisation, by which the means of social interaction, especially speech, are taken over by the child and internalised. Development proceeds when interpsychological regulation is transformed into intrapsychological regulation. Teaching, which under a Piagetian model may wait upon development, is in fact seen to be its decisive motive force. They further highlight the importance of Vygotsky's notion of the zone of proximal development and his hypothesis that children would be able to solve problems with assistance from an adult or more capable peer before they could solve them alone. This led to the conclusion that the zone of proximal development could be used to identify those skills most amenable to instruction. According to experiments conducted by Forman, it appears that a similar process to the interpsychological-intrapsychological regulation may also occur in collaborative contexts where neither partner can be seen as "more capable", but where partners may assume separate but complementary roles. Each partner seems to provide some of the same kind of assistance as that described as scaffolding by Bruner (1985). Forman and Cazden conclude that collaborative tasks require the construction of a common set of assumptions, procedures and information and that children need to integrate their conflicting task conceptions into a mutual plan. They observe that one way to achieve this might be to assume "complementary problem-solving roles".

Jones and Mercer (1993) trace the development of some of the theories of learning which are of relevance to the use of computers. In particular they highlight behaviourism, constructivism and socio-cultural theory in the tradition of Vygotsky. They also draw attention to the notion of inherited

Eysenck (e.g. Eysenck, 1953). In their analysis they identify behaviourism and constructivism as theories of learning which embody a strongly individualistic conception of learning, which they observe has dominated learning theory and educational practice in this field. They also point out that, in British education, one can see the influence of the theoretical position associated with *IQ* which leads to the view that academic success or failure is largely determined by the inherited structures of the brain. This perspective also is an individualistic one. Outside the "peculiar circumstances of the examination room", they observe that much learning, not least in relation to the use of computers, consists of the sharing of knowledge. They provide an example through the consideration of word processing whereby anyone who learns word processing comes to possess the knowledge of the software designers and to share this with them. This in turn has created a subset of our cultural resources which has come to be termed "word-processing skills". They argue that one measure of successful learning might be when two or more people manage to share their knowledge and understanding so that a new cultural resource is created which is greater than the knowledge and understanding that any of the individuals previously possessed.

Jones and Mercer argue further that the theoretical perspective offered by Vygotsky offers a framework which accommodates such a communicative, culturally orientated conception of human learning. In developing this argument they observe that Piaget's individualistic approach has probably had the most significant influence upon British education and that these are "still early days in the neo-Vygotskian era" with, as yet, little evidence of socio-cultural theory having influenced the educational software design community. In view of this, it is particularly interesting to note the following from Wood (1994), writing in a publication of a leading educational software and hardware design company, who predicts that "the recognised importance of social interaction as a basis for learning and conceptual development, coupled with an increased reliance on collaborative learning, will underwrite the continuance of group-based educational provision".

In proposing their view on the value and relevance of Vygotsky's approach, Jones and Mercer draw attention to the social aspects of cognition. Firstly there is the vital role that language plays in cognitive development, problem solving and learning. This is based upon Vygotsky's proposition that acquiring a language enables a child to think in new ways, so that a new cognitive "tool" for making sense of the world becomes available. Secondly there is the conceptualistion of children's learning capability in an essentially interactive manner based upon the concept of the zone of proximal development. Attention is drawn to the emphasis which Vygotsky placed on two important cognitive functions of human language. Firstly, it imparts a unique quality to human thought. Secondly, it provides a medium for teaching and learning. Therefore human knowledge and thought themselves can be seen to be fundamentally cultural and also can be seen to derive their distinctive properties from the nature of human communication. Accordingly they conclude that Vygotsky's theory "can accommodate" the role of the teacher as "someone who is an active communicative participant in learning, and not someone who simply provides rich *learning environments* for children's own discoveries (a la Piaget) or reinforces appropriate behaviour if and when it occurs (in the behaviourist mode)". They continue by observing that "like many valuable insights into human life, Vygotsky's assertion of learning as communicative may seem to have a certain self-evident quality" and that its acceptance, which the empirical findings of this study would support, could have significant implications for our conceptions of both the role of the computer in the learning process and also the role of the teacher in relationship to the use of computers in the classroom. They argue that a communicative approach might place less emphasis on the relationship an individual learner has with the computer (where the computer is viewed as either an "impersonal tool for *autonomous learning* or as a surrogate, robot teacher") and more on the computer as a medium for the facilitation of communication between teacher and learner.

In elaborating on this comparison Jones and Mercer cite Cole and Griffin (1987) who report on research and development in the context of science and mathematics education. They contrast two metaphors for computer-

..., the first of which is the computer as an agent, operating as a "partner in dialogue". This view implies that the student-computer relationship can be regarded as analogous to the student-teacher relationship, with the computer replacing the teacher. Within such a framework the computer has a role in providing structured hints, well-timed feedback and a wealth of factual knowledge. Cole and Griffin argue that it this metaphor that underlies the bulk of research on computers and education at the present time and that it "leads naturally to dreams of a *teacher-proof* curriculum". Their second metaphor, which serves to outline their own philosophy, is that of the computer as a medium, "not replacing people, but reorganising interactions among people, creating new environments in which children can be educated and grow by discovering and gaining access to the world around them". This metaphor emphasises the potential of computers for "reorganising instruction in the classroom and for making possible the extension of education beyond the classroom".

Cole and Griffin also argue that "successful introducers" of computers into classrooms are as much "*orchestrators* of their students' activities as they are occupants of the usual role in a teacher-led group". They compare the introduction of computers into the classroom with other innovations; e.g. "co-operative grouping strategies and activity-based curricula for science and maths", and consider the resulting need to redefine the role of the teacher. They point out that in such other cases of innovation, role specifications are an overt and articulated element, whereas with the introduction of computers "the specification of the teacher's role is easy to overlook"; but they also argue that it is "essential to arranging for the attainment of learning goals".

Cole and Griffin support their assertion of the importance of teachers as *orchestrators* of computer-based activities by citing research from Shavelson et al (1984) and Newman, Griffin and Cole (1989).

Shavelson et al (1984) report on examples of "good practice" in science and mathematics education in primary and secondary schools. They described *orchestrating* teachers as those who "used a variety of instructional modes ongoing curriculum, and coordinated microcomputing activities with other instructional activities". Newman, Griffin and Cole (1989) offer a more explicit comparison between a "traditional" approach to computer-assisted instruction and one based upon a Vygotskian framework, which they refer to as the ZPD approach, referring to the zone of proximal development. They offer a critique of the traditional approach to computer-assisted instruction, especially prevalent in America, based on similar arguments to those of Skemp (1976) already referred to. They note that there is "no need or opportunity to understand the goal of the sequence while learning the components" under the traditional approach. This is in contrast to the opposite emphasis of the ZPD approach since "the task that is the goal is being accomplished interactively from the beginning ... There is always the opportunity, therefore, for the child's actions to be made meaningful for the child in terms of the goal of the sequence".

Finally Jones and Mercer make reference to Crook (1991), who argues that what he refers to as "cultural psychology" offers one of the strongest theoretical bases for the evaluation of computer-based educational activity. He argues further that most evaluative studies of computer-based activities, like most of the practice they seek to evaluate, are based uncritically on an individualistic model of learning. He points to the fact that in most British classrooms, joint activity, involving pupils working in pairs or groups, is the norm and that socio-cultural theory appears to offer the conceptual framework most capable of dealing with this reality. This is the chosen theoretical basis for the evaluation of the resources and activities in Cycle 3 of this study.

Laurillard (1993) outlines what she terms "mediated" learning after Vygotsky, who proposed that "a scientific concept involves from the first a *mediated* attitude towards its object". She outlines her thinking with reference to "articulated" knowledge which by its very nature of being articulated "is known through exposition, argument, interpretation; it is known through reflection on experience and represents therefore a second-order experience of the world". Therefore, she argues, education must act knowledge has this second-order character, it relies heavily on symbolic representation as the medium through which it is achieved. She observes that this is usually language, but that it may also be mathematical symbols, diagrams, musical notation, phonetics or any other symbol system that can represent a description of the world and requires interpretation. She notes that the difficulty of this has attracted a fair amount of attention at the level of school mathematics but that "surprisingly little" has been done on how students interpret teachers' language, how they read academic texts and how they interpret graphical and symbolic information. It is in relation to this latter aspect of interpreting graphical information that this study reaches its final focus and offers a detailed analysis of some episodes of classroom discourse by pupils, in the context of using multimedia in the mathematics classroom.

3.0.0 METHODS OF ENQUIRY

3.1.0 INTRODUCTION

The approach to the research methods adopted in this study is best described by the term *case study.* This approach is in the interpretive tradition, which is itself one tradition within sociology. A distinctive characteristic of this approach is the emphasis upon qualitative data in contrast to earlier approaches which emphasise statistical techniques and the manipulation of quantitative data.

The methodology is consistent with the model of illuminative evaluation of Parlett and Hamilton (1972), the distinguishing features of which are that it involves the people who would naturally be participants in the research and values the actors' opinions as much as the observers. It also employs techniques such as triangulation (Elliott and Adelman, 1976) which involves the gathering of accounts of a situation from three quite different points of view e.g. those of the teacher, the pupils and a participant observer. Who in the triangle gathers the accounts, how they are elicited, and who compares them, depends largely on the context. By comparing one account with accounts from the other two standpoints a person, as one point of the triangle, has an opportunity to test and perhaps revise on the basis of more sufficient data. Kilpatrick (1993) describes the role of the researcher using an interpretive approach as "entering the encounter to understand and not to judge".

Burgess (1985) has identified a number of characteristic attributes of a qualitative approach to research which have been found to be particularly relevant to this study. He notes that the focus of the study is on the observed present but the findings are contextualised within a social, cultural and historical framework. The study is conducted within a theoretical framework and while there may be some questions to orientate the study, it is anticipated that further questions may arise during the course of the process. The research involves close, detailed and intensive work and the researcher participates in the social situation under investigation. The participant's account of the social setting. Unstructured or informal interviews may complement the observational account. Other methods of investigation may be used to complement the qualitative methods used. Decisions regarding the collection and analysis of data take place in the field and are the products of enquiry. The researcher attempts to disturb the process of social life as little as possible. Research reports disseminate the knowledge gathered without rendering harm to the informants and take account of ethical considerations related to both the researcher and the researched. Finally the researcher monitors the dissemination of materials and provides feedback to those who have been researched.

In the field of research on the use of computers in education, writers have argued for similar approaches in recent years. Beynon (1991) calls for a shift from a perspective which concentrates on the technical and cognitive aspects to one which includes the social and cultural. He outlines an approach based upon qualitative research and this is supported by the arguments of Goodson and Mangan (1991). It is suggested by Walker (1987) that there should not be a polarisation between two mutually exclusive research paradigms and he calls for the consideration of both quantitative and qualitative approaches.

The research methods adopted in this study have also been significantly influenced by action research methodology, and the action research cycle in particular. This is fully outlined in the following section. Action research has been described by Elliott (1991) as the study of a social situation with a view to improving the quality of action within it. It has also been described by Carr and Kemmis (1986) as a form of self-reflective enquiry undertaken by participants, such as teachers, in educational situations in order to improve their own educational practices, their understanding of these practices, and also of the situations and institutions in which these practices are carried out.

Although this study has not been an action research study, the overall approach has involved the investigation of educational practice, in the

... group work with multimedia. Further, it has illuminated the understanding of this practice and also of the situations in which this practice has been carried out. Accordingly the underlying principles of action research methodology have been found to be particularly appropriate.

3.2.0 THE ACTION RESEARCH CYCLE

Lewin (1946) describes action research as proceeding in a spiral of steps each of which is composed of planning, action and evaluation. He proposes a spiral of cycles which is summarised in Figure 1.

Action research - Lewin's model (1946)
Spiral of cycles

Identify general idea

Reconnaissance (fact finding)

General planning

Developing first action step

Implementing first action step

Evaluation

Spiral into:

Revising the general plan

Developing the second action step

Implementation

Evaluation

Revising general plan Etc

Figure 1

Kemmis and McTaggart (1982) identify four moments in the process of action research. The first of these is to develop a plan of action, secondly to act to implement the plan, thirdly to observe the effects of the action in the context in which it occurs, and fourthly to reflect on these as a basis for further planning, subsequent action and so on, through a succession of cycles. This spiral is summarised in the model shown in Figure 2, which is based on that of Kemmis and McTaggart.

Spiral of action research

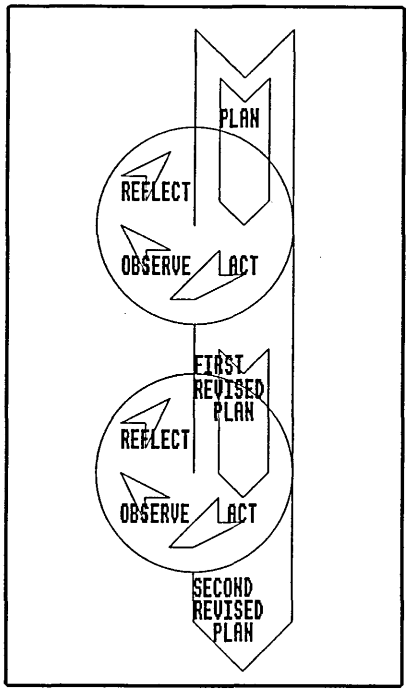


Figure 2

In his critique of Lewin's model, Elliott (1991) argues that the general idea should be allowed to shift, reconnaissance should involve analysis as well as fact finding and that implementation should be monitored. Elliott's modified model is summarised in Figure 3.

Action research - Lewin's model modified by Elliott (1991)

Identify general idea

Reconnaissance (fact finding & analysis)

General planning

Developing first action step

Implementing first action step

Monitoring and evaluation

Reconnaissance

Revising the general idea

Revising the general plan

Developing the next action steps

Implementation

Monitoring and evaluation

Reconnaissance (fact finding & analysis)

Etc

Figure 3

focussed upon background research relating to collaborative learning emerging, in the main, from the American research community and from Johnson et al (1984) in particular. The classroom research and development focussed upon the use of the *Domesday* database system, in the context a group work environment, at school A.

The second cycle began with a further period of reconnaissance or fact finding and analysis. The literature review was widened considerably to encompass more evidence from the perspective of the British research culture, with its emphasis upon collaborative rather than co-operative learning. It also developed more focussed strands in relation to research in mathematics education and to the use of computers, which was seen to be increasingly relevant. In addition, a further aspect of the reconnaissance prior to Cycle 2 classroom trials was the review of the findings which emerged from the IVIS Project trials schools. Finally, in this second cycle, there was the classroom research and development, involving the further use of the *Domesday* system in school B.

The third major cycle, Cycle 3, expanded the background to the study by focussing on the developing literature related to multimedia and mathematics education. In addition close attention was given to the consideration of theoretical perspectives on learning, which came to assume increasing relevance as this study developed, as a result of the consideration given to the role of the teacher and associated teaching and learning styles. With the evaluation of the multimedia package *World of Number*, the study began to develop a greater focus. This process was continued further with the development of classroom materials and approaches, which included an element from the *World of Number* package. This could be thought of as a series of sub-cycles, within the third major research cycle itself, or alternatively as a *process* of progressive focussing (Hamilton and Delamont, 1974). It is this latter conceptualisation which captures the essence of this study, which found its final focus in the analysis of the video tape transcripts of the groups working on the multimedia-based activities in Cycle 3.

3.3.0 DATA COLLECTION TECHNIQUES

Elliott (1991) outlines a list of techniques and methods for gathering evidence in the reconnaissance and monitoring phases of action research. The list is summarised in Figure 4.

Techniques and methods for gathering evidence (Elliott 1991)

- Diaries
- Profiles
- Document analysis
- Photographs
- Audio/video recordings (and transcripts)
- Use of an observer
- Interviewing
- The running commentary
- Teacher or pupil shadowing
- Checklists, questionnaires, inventories
- Triangulation
- Analytic memos

Figure 4

In planning the collection of evidence for this study emphasis was placed upon achieving triangulation. Accordingly in Cycle 1 feedback was gained from the pupils by means of pre-trial and post-trial questionnaires, video recording and post-trial semi-structured interviews. Feedback was gained from the teacher via ongoing and post-trial discussions in addition to written feedback, in relation to the classroom materials and their use in particular. My own observations and record of these as researcher formed a third perspective. A further perspective was achieved through the feedback obtained from a visiting HMI.

In Cycle 2, initial feedback was obtained from data collected via the review of the use of interactive video in schools, which served to reinforce some of the findings from Cycle 1 classroom trials. Further feedback was gained from pupils via pre-trial and post-trial questionnaires. The option of video recording was kept open but subsequently not utilised, for reasons outlined in Chapter 6. Feedback from teachers was planned via teacher diaries, ongoing and post trials discussions. In the event, the written feedback did not materialise. In addition there were my own observations as researcher and records of these.

The evaluation of the materials in Cycle 3 was started by means of initial impressions and reactions to the use of the materials, as an individual user, which were recorded in an ongoing diary. A further range of perspectives was gathered through the review of relevant literature, specifically related to the evaluation of the materials. This process was completed through initial classroom observation in the trial school and semi-structured interviews with teachers. The diary was used to record the observations and the interviews were audio taped and subsequently transcribed. Feedback on the classroom trialling was gained from the pupils by means of post-trial questionnaires, post-trial semi-structured interviews and video recording of the multimedia-based activities. The interviews were audio taped and subsequently transcribed, as was the video tape recording. In addition pre-tests, post-tests and delayed post-tests were conducted.

3.4.0 APPROACH TO DATA ANALYSIS

3.4.1 OVERALL APPROACH

Hamilton and Delamont (1974) offer an analysis of what they broadly term "anthropological" classroom research which is particularly relevant to the approach adopted in this study. They describe the anthropologist as one who uses an holistic framework, accepts as given the complex scene which is encountered and takes this totality as the data base. There is no attempt to manipulate, control or eliminate variables. At the same time there is no attempt to claim to account for every aspect of this totality in the analysis. A characteristic of the process is that the breadth of the enquiry is gradually give more attention to the emerging issues. From starting with a wide angle of vision enquiry zooms in and progressively focuses on those classroom features that are considered to be most salient. Thus they argue such an approach clearly dissociates itself from *a priori* reductionism which is characteristic of the more traditional *scientific* approaches. The process of progressive focussing has been a particular feature of this study, as outlined earlier.

3.4.2 ANALYSIS OF COLLABORATION AND LEARNING IN COMPUTER-BASED GROUP WORK

The approach of Pozzi, Hoyles and Healy (1992) was given particular attention prior to Cycle 3 classroom trials. They report on a methodology for analysing collaboration and learning in computer-based group work, which developed as part of the project outlined by Eraut and Hoyles (1989). They argue that any methodology for analysing the processes underlying computer-based group work must take into consideration the inter-relationship between the task, the computer and the communication between peers. Their methodology attempts to capture the relationship between the group processes, individual progress and group outcome. They designed tasks so that, to be successful in terms of group outcome, the following would need to be negotiated:

- Task Management - the organisation of people, task components and resources (including computers)
- Global Targets - the mathematical and programming ideas which underpin the group outcome
- Local Targets - subcomponents of the task which can be legitimately allocated to subgroups.

They collected process data through researcher notes, video recordings of the whole group and the screen output of one computer. The group was given a semi-structured interview after each task in which pupils were asked for their perception of the task, the group and individual learning. A further interview was also conducted with the class teacher. Their aim was to capture the essence of the groups' approaches.

As part of their approach Pozzi, Hoyles and Healy also devised a scoring of individual involvement in an episode as either active or non-active. A pupil is active if she makes a contribution to any discussion or interaction with the computer, and non-active otherwise. They stress that their analysis necessarily simplifies group dynamics in order that comparisons can be made at some level about the processes and interactions and note that this quantitative analysis forms just one part of the development of group and individual profiles, which also incorporate qualitative descriptors.

Reporting upon their experience at a later stage, Hoyles, Healy and Pozzi (1994) indicate that they encountered a number of difficulties in developing their coding techniques, many of which stemmed from "a mismatch between our coding and the qualitative data". They found that similar collaboration scores were obtained for settings which they knew to be qualitatively different. For example, smaller sub-groups almost by definition were more likely to receive higher collaboration scores than larger ones, and the scoring system did not take account of communication between sub-groups at different computers. The involvement score for each pupil was also found to be problematic when they attempted to compare them across different task settings. For example, a pupil's involvement in a setting was not independent of the involvement of all their peers, and this interdependence was not reflected in the initial coding.

An attempt was made to develop a more complex coding which reflected group interdependence but the result was "a coding that was far too complex to be workable". As a result their attention "shifted to giving more detailed textual descriptions of the group processes". They developed richer case studies of each task setting using all the available data. These were focussed on dimensions which emerged during the process of analysis, such as: pupil characteristics, relationships and knowledge; group management; group interaction; extent of sharing; pupil involvement; computer-based strategies; pupils' perceptions; group and learning outcomes. These findings reinforced my own ambivalence towards a reductionist approach (Hamilton and Delamont, 1974) and confirmed my own interest in developing a more qualitative one.

Hoyles et al had earlier indicated that they had decided not to rely upon transcription and the analysis of language utterances and gestures, which they regarded as "an impossibility in these settings". This was probably a reflection of the scale of their project, which involved several groups working simultaneously on a number of computer-based tasks. However, given the much smaller scale of this study and the difficulties which Hoyles et al had encountered, this option was given further consideration as a possible approach.

Consideration was also given to the use of categories describing patterns of interaction and learning which emerged from the findings of Hoyles et al. They identified patterns of interaction and learning, which are fully outlined in Chapter 2. In particular they define a continuum between a *directed* setting and a *mediated* one, with the former characterised by the domination of one or two pupils and the latter being more negotiated. In the directed setting pupils were categorised as either *directing* or *directed*, according to whether they adopted the position or were influenced by it. Within each of their settings, Hoyles et al describe ways in which individual pupils interacted using a number of categories. For example, they used the categories of *talking* and *encoding,* with the latter sub-divided into *encoding* on the computer or *writing* on paper. They categorise a pupil as a *talker* when her level of talking is at least half that of the most talkative pupil. In planning the data collection for Cycle 3 classroom trials this approach was given close consideration. It was decided to attempt to use these categories, with the addition of two further ones of *active listener* and *non-active participant* as the basis for a group interaction profile (see Appendix 2(i)). The eventual categories were:

Directing
Directed
Mediating
Talking
Encoding
Writing
Active listening
Non-active participant

situations were designed which were planned to involve all pupils in some or all of these categories. The group interaction profile was designed with a view to monitoring the interaction in this way. However, early in the classroom trials it became very clear that the use of the profile as an ongoing monitoring device was entirely impractical. There was simply too much happening in the classroom situation to pay attention to it. Consideration was then given to its possible use in relation to the analysis of the video recording, but in the event a quite different approach to this analysis was taken. The major influence in the early stages of the development of this alternative approach to the analysis of the video tapes was the work of Mercer (1991) and also Edwards and Mercer (1987) whose method was based upon the detailed transcription of utterances and gestures, which had been rejected by Hoyles et al. This approach was of a much more qualitative nature and was far more consistent with my preferred approach overall. It had the advantage of leaving the discourse untouched in the context of a process of progressive focussing, thus allowing for patterns and issues to arise from the data analysis itself.

3.4.3 ANALYSIS OF VIDEO TAPE RECORDING

The focus of the study reported upon by Mercer (1991) is the content and context of educational discourse from a theoretical perspective strongly influenced by the work of Vygotsky. He describes the analytic methods adopted as being similar to those of ethnography, "in that we were similarly concerned with the minutiae of what was said and done; and we were interested in participants' accounts and interpretations of what they said and did". However he describes how the concerns of his project team were significantly different from the sociological themes of many classroom ethnographers, being concerned as they were with the more psychological themes of knowledge and communication.

In common with my own experience, Mercer observes that following his preliminary work, he came to realise that other existing methods for analysing classroom discourse were unsuitable for his needs. He refers to commonly employed methods such as of interaction analysis and systematic observation as examples e.g. (Croll, 1986). Such methods involve all events being assigned by observers to previously defined categories, with the coded results thus obtained providing the data for the next stage of analysis. The resulting effect of such a process is that the discourse itself does not remain accessible to analysts after the observed classroom activity is over. Thus the analysis is "wholly dependent on the *a priori* adequacy of the category scheme and on the observers' skills in applying it". Mercer observes further that as his interest lay in the "continuous, cumulative processes by which a common knowledge is developed in classrooms", and also because full records of what was said and done were being made, that his needs would not be served by reducing the data to numerical frequency codings. Mercer's approach was seen to be consistent with the process of progressive focussing adopted in this study.

The resulting method employed by Mercer involved the complete transcription of all the discourse recorded on videotape. In addition, any information on the physical context and non-verbal communication, which was necessary to make sense of what was said or done, was added alongside this relevant section of the transcript. He describes this information as *context notes* and adds that the development of this was "undoubtedly the most important part of the process of analysis". It should be noted however that all the initial transcription was undertaken by a project secretary and therefore this would have been the first occasion for the researchers to study the actual video tape in close detail. He describes how one of his aims was to track themes or elements of knowledge through lessons and also that they noticed how *continuity* of experience was established through discourse. Mercer also outlines his other concerns with both the *content* of discourse and also its *context*, which were considered to be highly relevant to this study. In relation to context he explains how "at the most obvious level, our concern with context meant that we noticed how the physical 'props' of the classroom - equipment, drawings, texts, computer-screen representations - were invoked by speakers to support the discourse".

consistent with the overall direction in which this study had developed up to that point in time and was therefore adopted as the basis for the analysis of the video tape transcripts in Cycle 3. The video tapes were viewed and transcribed with the addition of the context notes, as the transcription process developed. The initial stage of data analysis involved the identification of particularly interesting episodes of pupil-pupil discussion, which were characterised by high levels of interaction, the use of highly problem-specific language, the use of gestures etc. At a later stage of the process, examples of lower levels of interaction were highlighted in order to compare and contrast these with the former.

3.4.4.0 INTERPRETIVE FRAMEWORK FOR THE ANALYSIS OF THE VIDEO TAPE TRANSCRIPTS

In reflecting upon the methodology adopted towards the video tape transcripts, the need for an interpretive framework for the analysis of the data soon became evident. Such a framework might have been devised, based upon the emerging analysis of the data. An alternative was to seek to adopt or adapt an existing framework. In the event, the approach adopted by Teasley and Rochelle (1993) was found to be particularly resonant with this study and was consequently adapted to form the chosen framework.

Teasley and Rochelle report on a study which is intended to illustrate the use of the computer as a cognitive tool for learning that occurs socially. The study is concerned with the question of how students construct shared meanings in relation to modelling activities, in the context of a Newtonian microworld. This microworld is a computer package which is described as "a graphical and dynamic simulation of a physicists' mental model of velocity and acceleration". They outline a view of learning which is in the tradition of Vygotsky, in that it is based upon a view of learning as a fundamentally social activity i.e. that understanding is built through social interaction and activity and that concepts and models are social constructions resulting from "face-to-face participation" in activities.

collaboration, which they argue involves not only a microanalysis of the content of students' talk, but also how the pragmatic structure of the conversations can result in the construction of shared knowledge. In order to understand how social interaction affects the course of learning, Teasley and Rochelle argue that it requires an understanding of how students use coordinated language and action to establish shared knowledge, to recognise any divergences from shared knowledge as they arise, and to rectify any misunderstandings that impede joint work.

A starting point for the development of their framework is the definition of *collaboration* as:

> A coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem.
>
> (Teasley and Rochelle, 1993)

They also make the distinction between *collaborative* and *co-operative* problem solving. The latter is seen to be accomplished by the division of labour among participants, where each member is responsible for a portion of the problem solving. In contrast, the former involves the mutual engagement of all in a coordinated effort to solve the problem together.

3.4.4.1 JOINT PROBLEM SPACE

Teasley and Rochelle draw on ideas from pragmatics, conversation analysis and protocol analysis to describe how communicative exchanges function to construct and maintain the notion of what they describe as a *Joint Problem Space*. They propose that social interactions in the context of problem solving activity occur in relation to a Joint Problem Space (JPS). This is defined as a shared knowledge structure that supports problem solving activity by integrating the following:

(a) goals
(b) descriptions of the current problem state
(c) awareness of available problem solving actions
(d) associations that relate goals, features of current problem state and available actions.

This idea is developed further with the proposition that the fundamental activity in collaborative problem solving occurs by means of the engagement of the participants in an emergent, socially negotiated set of knowledge elements that together constitute a JPS.

A number of "structured discourse forms" are described which conversants use in everyday speech to achieve mutual intelligibility. These utilise language, bodily action and combinations of words and actions. The authors argue that students use the structure of conversation to continually build, monitor and repair a JPS. They also describe some *categories of discourse events* that they have used in their analysis such as turn taking, narrations and coordinations of language and action.

3.4.4.2 TURN-TAKING

This is the most pervasive and general category of discourse and can be made up of specific discourse units such as questions, acceptances, disagreements and "repairs", which represent ways of taking a conversational turn. The flow, content and structure of turns can be used to as a measure of the extent to which participants in a conversation understand each other.

3.4.4.3 REPAIRS

Because collaboration also involves periods of individual activity, collaborative activity can produce periods of conflict in which individual ideas are negotiated with respect to the shared work. These periods of conflict may signify a breakdown in mutual intelligibility, rather than continuing collaboration. Attempts to reduce the conflict by resolving misunderstandings are a feature of a working style in which a shared conception of a problem is maintained. Such attempts are described as *repairs* and as such represent the the method by which participants can deal with problems in speaking, hearing or comprehension of dialogue.

3.4.4.4 COLLABORATIVE COMPLETION

This category describes an exchange which distributes a compound sentence over discourse partners i.e. one partner's turn begins a sentence or

Rochelle refer to a particular form of such a collaborative completion as a *socially-distributed production.* This notion refers to a compound sentence of the form IF-THEN which is distributed across turns, providing an opportunity for acceptance or repair of conditional knowledge.

3.4.4.5 NARRATIONS

Narrations represent a verbal strategy that enables partners to monitor each others' actions and interpretations. Continued attention to narrations and accompanying action can signal acceptances and shared understanding, whilst interruptions create an immediate opportunity to rectify misunderstandings.

3.4.4.6 LANGUAGE AND ACTION

Participants in collaborative activity are not wholly dependent on language to maintain shared understanding. A major role of a computer in supporting collaborative learning can be in providing a context for the production of action and gesture, which can serve both as presentations and acceptances. The simultaneous production of matching language and action by separate partners can provide opportunities for acceptances of new ideas and also for repairs.

3.5.0 SUMMARY

In summary, the action research cycle has been found to be highly relevant approach to the study as a whole. In particular, three major cycles can be identified. Cycle 1 focussed upon the initial background research relating to collaborative learning and upon the use of the *Domesday* database system, in the context a group work environment at school A. In Cycle 2, the literature review was widened considerably and also developed more focussed strands in relation to research in mathematics education and to the use of computers, in particular. A further aspect of the reconnaissance was the review of the findings which emerged from the IVIS Project. Finally, in this second cycle, there was the classroom research and development, involving the further use of the *Domesday* system in school B. The third major cycle expanded the background to the study by focussing on the addition close attention was given to the consideration of theoretical perspectives on learning, which came to assume increasing relevance as this study developed. With the evaluation of the multimedia package *World of Number*, the study began to develop a greater focus and, through a process of progressive focussing, attention came to be centred on the multimedia-based group activities. The final phase of the study involved a microanalysis of the resulting classroom interaction and discourse.

The techniques and methods for gathering evidence, associated with an action research approach were found to be highly relevant to this study. Most of the techniques and methods outlined by Elliott (1991), and summarised in Figure 4, were utilised at some stage of this study. Throughout all stages emphasis was placed upon achieving triangulation, where this was appropriate.

The data collected in the ways outlined was analysed on an ongoing basis and the overall approach to data analysis could best be described as a process of progressive focussing, consistent with the approach outlined by Hamilton and Delamont (1974). As a part of this process, the work of Pozzi et al (1992) and Hoyles et al (1994) was given close consideration. However the work of Mercer (1991) was found to be a more fruitful approach to the analysis of the classroom interaction and discourse. Subsequently the framework for the analysis of collaboration, as outlined by Teasely and Rochelle (1993), was found to be a highly relevant interpretive framework for the analysis of this data.

Finally, on the question of validity, this study has sought to achieve it mainly through a process of triangulation as described earlier. In Cycle 1 this was achieved by comparing the perspectives of the researcher, classroom teacher, pupils and also an outside observer. In Cycle 2, the Field Officers reports from the IVIS trial schools provided a substantial body of evidence which had been collected nationally. In addition, the perspectives of the researcher, classroom teachers and the pupils were compared. Triangulation at the evaluation stage of Cycle 3 was achieved package, through initial classroom observation, feedback from teachers and also by means of a review of relevant literature. At the stage of classroom trials, this was achieved by comparing the views of researcher, classroom teachers and the pupils. The approach to the analysis of the video tape transcripts was quite different in nature. The analysis of these transcripts was carried out from a particular perspective based upon an interpretive framework. This framework reflected a Vygotskian perspective which had developed over the course of this study. Hence the analysis of the data fully reflects the bias of the researcher and the particular chosen perspective, at this stage of the study.

4.0.0 CYCLE 1: CLASSROOM TRIALS AT SCHOOL A

Cycle 1 classroom trials took place during November 1988 at School A, which is a comprehensive school in a South Yorkshire mining community. This particular school was chosen primarily because it was one of a small number in the region to have the use of the BBC Domesday interactive video system. The classroom trials were discussed and agreed with the Head of Mathematics who reacted very positively to the initial approach. In presenting the project, an emphasis was placed on the underlying philosophy involving the encouragement of an investigatory approach to the learning of mathematics, the use of real contexts, collaborative group work and the use of the computer/IV system in an integrated way.

The classroom materials were developed on the theme of *Trees* and use was made of the National disc of the Domesday package which contains 50000 photographs, 250000 pages of text, 24000 maps and many millions of statistics. These materials consisted of a pupil booklet of activities on the theme of *Trees* and a further pupil booklet on *Using Domesday,* together with supporting Teachers' Notes. These materials were written as part of the *Century Maths* project and there was considerable feedback on their development from trial schools attached to the *Century Maths* project prior to Cycle 1 classroom trials. The materials were subsequently published as part of *Century Maths* (see Buxton, Hudson, Gillespie, Miln, Eyles and Singh (1991); Hudson and Gillespie (1991) and Century Maths (1991)).

4.1.0 THE CLASSROOM MATERIALS

The materials were written for Year 8 pupils and designed in a way that would encourage collaborative group work and provide opportunities for activities of a practical nature outside the classroom. The initial scenario involves the pupils being presented with a problem of how to cut down a diseased and storm damaged elm tree safely. This was envisaged as a whole class introductory activity to the theme of *Trees*. The pupils are asked to think about and discuss the things that will have to be considered its surroundings. It was considered likely that most pupils will want to find the height of the tree. Therefore it is suggested that a clinometer might be used, although the pupils are encouraged to devise and try out their own methods. They are asked to make a classroom display of their methods and results and are encouraged to consider further activities around the same theme. For example, a further activity focuses on the problems involved in moving the tree, which could lead to some complex mathematics. Another activity involves the design of a playground, within a park, involving scale drawing and the estimation of area. It also involves estimating the amount and cost of grass seed for grassing part of the area. Several activities are included and it was not intended that all pupils would follow them in a particular order or necessarily attempt all of them. In designing the materials the assumption was made that there would be several activities in progress at any one time. This would enable the use of the IV system to be shared out amongst the groups over a period of time.

4.1.1 USING DOMESDAY

The theme of *Trees* is maintained as groups of pupils come to use the Domesday system, since the initial activities involve some of the considerable amount of data on trees in the UK, that is contained on the disc. Using the "FIND" option and entering "Trees" the first 21 from over 100 items of data are listed on the screen. The information is grouped into four categories which are Pictures, Maps, Text and Data. The pupils are invited to select an item from each category and thereby familiarise themselves with the system and how it works. The first item is a series of still frames of various park scenes. It is possible to extract extra information on each one by using the appropriate option on the menu bar.

On selecting an item of text, for example on acid rain, a screen of text appears. In one case the text is from a newspaper article about acid rain, which contains a considerable amount of data of a numerical kind. It is possible to page through the screens as this particular article consists of five pages or screens. There is the additional option of printing out the text.

On selecting an option involving "Maps", the user is invited to specify an area by type (e.g. COUNTY) and by name (e.g. SOUTH YORKSHIRE). A data map is then presented on the chosen area. For example if one particular item is chosen then data on Ash trees in South Yorkshire is provided. On this particular data map there are three categories of data indicated by black, blue and red shading. Black indicates that no data is available, blue that the species is absent from that particular area and red that it is present. The basis of the data is available within the associated text option and is in fact based upon the occurrence of at least one example of the species within a 10 by 10 kilometre square.

The fourth category entitled "Data" has the most potential for use in the mathematics classroom, as many easily recognisable mathematical activities fall within this category. For example, if the appropriate choice is made, a bar chart is presented dealing with data on "Broadleaf Planting in England". The system has various idiosyncrasies in that some explanatory titles are truncated due to the width of the message box. A variety of changes are available to the user for each graph that is presented. For example, the graph is presented for all regions and it is possible to select a particular region e.g. NE and then to select "Replot" for the graph to be redrawn. Similarly it is possible to select particular time intervals for the data. Initially the data is presented for "All years" which includes all data available since records began. From the latter part of the 19th century this data is grouped into ten year intervals so, for example, it is possible to select data for the period 1961-70 only. In addition it is possible to change the "Chart Type" so that, if a pie chart is required, this will be replotted using the same data. Other options are available which were considered too sophisticated or to complex an operation for the target age range.

Having become familiar with the system, the intention was to encourage more open-ended exploration of the data both on the theme of trees but also more widely into areas of particular interest to the user.

4.2.0 THE TRIALLING

The class which was able to work on the project was a Year 9 group of average ability. It was agreed with the class teacher that they would work on the project for approximately two to three weeks. I was able to be present for the majority of the lessons. My role was to work with individuals and small groups and to concentrate on those groups using the Domesday system, as far as possible, in the initial stages of the project at least. It was also my aim to observe the whole classroom situation, in general. It was agreed that, following the initial introduction of the theme, I would take small groups of pupils in turn and aim to familiarise them, as quickly as possible, with the computer system and contents of the videodisc. The initial period for each group was approximately fifteen minutes which, although limited, did allow for the whole class to have some initial experience with the system within two lessons.

The project was introduced by the teacher as a whole class activity, in the first instance, but with a degree of direction which had not been anticipated. My expectation had been that the situation would be presented to the whole group, any immediate questions would be discussed and then small groups would consider, discuss and begin to formulate their own plans. A crucial role for the teacher was envisaged, which involved intervention in these discussions and the facilitation of progress. However I found myself increasingly redundant during this first lesson. This led me to realise that I had made certain assumptions about the approach and thinking of the teacher, with whom I was working, which were in fact wide of the mark. These assumptions had been made on the basis of the initial discussions with the Head of Department, who indicated a strong agreement with the overall approach which had been outlined.

The class teacher had prepared a very prescriptive supplement to the classroom materials consisting of a list of seven questions, each of which emphasised the recording of information. For example, question 1 required the pupils to <u>copy</u> the plan, which was already provided in the pupil materials. They were then directed to <u>label</u> the best place for the tree to fall, choosing the position of the fallen tree. Subsequent directions involved marking the scale, making a list of possible methods, writing down any equipment needed and finally writing down an estimate of the height of the chosen tree.

In discussion with the whole group, attention was focussed on the list of seven questions. The range of possible methods was discussed with the whole group in some detail. During the initial stages individual pupils were quite imaginative in their suggestions for how the height of the tree might be found, suggesting amongst other ideas that of comparing lengths of shadows. However, as a result of conducting the discussion with the whole group, only a minority were able to contribute ideas and the overall level of involvement was low.

In designing the classroom materials, it was assumed that the pupils would be working in small groups for a large proportion of the time. This particular activity had been designed with a whole class introduction in mind, as previously outlined. However it was envisaged the class would subsequently break down into small groups to discuss their own ideas. The pupils were encouraged to make an estimate of the height but also to compare this with a friend. An implicit assumption was made of a social situation in which the pupils discussed their ideas with each other and also with the class teacher. In contrast the implicit assumption, underlying the style of working of the class teacher, was of considerable direction from the teacher, both in terms of the task and also in terms of discussion which was entirely teacher led. There was also a strong emphasis on the recording of information in writing by individuals and no encouragement for social interaction.

Following the initial whole class discussion of the problem, the focus shifted to the planning of the following lesson, when the pupils would be working outdoors on the practical activity. This involved establishing the groups and deciding on which methods each group would try. Equipment needs were also agreed upon. One positive outcome was that the class was outdoors in groups and measuring the heights of their chosen trees.

During the second lesson the class worked in groups of three or four collecting several sets of readings for each tree. The pupils had been engaged in activities involving the estimation of angles and distances and also using trundle wheels and clinometers. The class teacher indicated that he thought this lesson had gone very well. The groups had been well motivated and the weather had been kind.

During the third lesson, the classroom situation was quite different from that at the start, with individuals and small groups working on their own tasks. The atmosphere in the classroom was very positive and there was a high level of involvement on the part of the pupils in their various tasks. These consisted mainly of using their measurements to do scale drawings in order to calculate the height of their trees. The class teacher seemed to be much more relaxed and was kept busy in discussing the work of individuals and small groups.

At this stage the groups were given the opportunity to work at the system for a short period to become familiar with the general method of operation. This was probably not the most effective use of my time, as I found myself repeating the same instructions time and again. The advantage was that it provided the opportunity for all the pupils to have some hands-on experience fairly quickly. Each group had a short period at the system during a single lesson. Subsequently each group was given approximately fifteen minutes each on alternate lessons. Hence the time for each group over a three week period was limited to about three or four sessions each at the computer. However some groups did choose to spend more time on the system outside normal lesson time.

On the first occasion that the system was used, it was based within the library area and groups of pupils came in turn. This was not very satisfactory because I was cut off from the whole class activity and also because of the delay caused, between groups changing over. Subsequently system to be wheeled into the classroom. This not only improved the efficiency of the change-over but also kept me in touch with the whole class situation and allowed me to use my time much more flexibly.

Once I had worked with each group for two fifteen minute sessions each, I was able to circulate more generally around the class as a whole. At this stage, after five or six lessons, the groups were beginning to work on their final displays. There was a variety of different tasks, both across the classroom as a whole and within each group. It was quite clear that the pupils had negotiated a division of labour during the course of the project. It was at this time that I was able to video record the classroom situation which represented a considerable transformation from the first lesson. Also at this time I arranged for a visit to be made by an HMI who was interested to see classroom applications of the use of Domesday. His impressions of the general classroom atmosphere were positive. Following his visit he discussed the project with the Headteacher and Head of Department.

4.3.0 DATA COLLECTION

Feedback was obtained from a number of sources which included pre-trial and post-trial questionnaires to the pupils, the teacher's diary, video tape recording, small group post-trial audio taped interviews together with my own ongoing observations of the classroom situation and discussions with the teacher, pupils and the HMI. The variety of perspectives was designed to ensure triangulation of data. In the event feedback was gained from four sources i.e. the teacher, the pupils, the researcher and also the non-participant observer. The analysis of the data which was collected is presented in following sections.

4.3.1 TEACHER FEEDBACK

As indicated earlier in this chapter, the teacher was initially very prescriptive in his approach. In his subsequent feedback, he commented that:

> *The pupils needed much more definite guidance on how to proceed than that given in the booklet.*

In response to being asked whether his role had changed whilst using the material, he responded by indicating that he had spent much time in translating/expanding the pupil's booklet and reported that:

> *In the previous half-term that I had taught this set, I had not used this "working-in-groups" approach.*

He thought that the class reaction to the material had been *good* and *positive* and described their reaction to it as:

> *Better than proper maths!*

He was asked whether any children surprised him by going beyond his expectations and his reply was:

> *Pupils with self-reliance and initiative came to the fore more readily.*

His overall reaction was positive:

> *It fits in well with GCSE style of teaching i.e. an "understanding through investigation" approach.*

At the end of the project he did not feel that the pupils had *covered as much maths* as they would otherwise have done. He did however identify much scope for interdisciplinary work with these materials and had arranged for a video on Acid Rain to be shown at the start of the following term. He also gave indications that he intended to liaise with a colleague in the Geography Department on this.

4.3.2 POST TRIAL FEEDBACK FROM NON-PARTICIPANT OBSERVER

At the conclusion of the trials, the experience as a whole was discussed with the visiting HMI. I was particularly interested in comments which might be made following observations of the classroom situation. These emphasised the lively classroom atmosphere and high level of pupil motivation. However the HMI also had discussions with the Headteacher and Head of Department and a number of the questions he asked of me focussed upon the benefits of the project to the school. He was interested in it became apparent that the school had had one set of aims for the project and that I had a different set. Furthermore I had been unaware of those of the school although they had always been clear about mine. It became obvious that the school had seen the project primarily as a staff development exercise, which had not been made explicit to me at any stage. Had I been made aware of the situation at the outset, then I could have made a decision about whether my aims could be met in conjunction with those of the school or not. In all likelihood I would have decided to proceed given that these twin aims were not entirely incompatible. However I would certainly have altered my approach and would have taken a very different role at the start, in particular.

4.3.3 PUPIL RESPONSES

In the pre-trial questionnaire 35% of the pupils expressed a liking for variety in the subject and the most common non-content specific dislike was repetition or "going on and on" which was expressed by 42% of the group. Homework was cited by 12%, as well as general expressions of passivity e.g. "too much teacher talk". One respondent categorically disliked maths. 62% indicated that they always or mostly work individually while 50% clearly preferred to work in pairs or in groups. Several pupils made reference to teacher disapproval of them talking and hence of pressure to work alone. Responses to the question asking pupils to rate their ability at maths indicated that 73% regarded themselves as "alright" or better at the subject. One pupil classing herself as "alright" did qualify her response by adding "not rubbish as Mr D thinks".

In the post-trial questionnaire all the pupils responded positively expressing that they had enjoyed the work with the major reason given by 55% of the group being that it was different/better than "normal" maths. Further analysis showed that 28% specifically mentioned working in groups and 28% also indicated the use of the Domesday system as reasons for enjoying the work with only one pupil mentioning both. All the pupils thought that the work was better or much better than normal mathematics lessons with 84% indicating their positive attitude towards working in groups by experience as she did not like the other members of her group but 83% of the pupils thought that the standard of their work had been *good* or *very good.* The largest proportion of these (31%) indicated that they thought the final display was good or better than expected. In responding to the question on the extent of their enjoyment 42% reported that they had enjoyed using the Domesday system *very much* or *quite a lot* but 56% thought that it was merely *OK.* A significant minority of pupils (14%) indicated that they had not had enough time on the system.

Individual comments from the pupils themselves provided a greater insight into their thinking. These comments were in response to a question on whether the pupils had enjoyed the work together with a request for a reason for their answer:

> *I enjoyed working together in groups because you help each other in the things you do.*
>
> *Damian*

> *Because we learned a lot about trees, how to use the computer .... its not every maths lesson you get to do large drawings and title pages and going outside to measure trees.*
>
> *Paul*

> *It's different from normal maths. Learn more.*
>
> *Lee*

> *Using the computer and we learned more on acid rain.*
>
> *Simon*

> *Well we didn't have to do much writing ..... and we could talk to our friends a bit.*
>
> *Harjinder*

> *...... a change from normal routine.*
>
> *Rob*

everyone to see.

Michelle

Because you were working in groups and drawing and you did not have to write loads and loads.

Kerrie

Several commented upon learning about Acid Rain:

I learned about acid rain and other things.

Michelle

We learned about acid rain and where its going over Scandinavia.

Damian

I learnt that acid rain can damage trees and people are trying to stop it.

Harjinder

I learned things about acid rain and trees.

Kerrie

I learned about Acid Rain and how it destroys the trees.... I would like to do some more work on it.

Darren

I learnt just how much England is responsible for pollution in Europe.

Anthony

There were some less enthusiastic comments several of which concerned a lack of time on the system but some questioning the purpose of the activity:

We didn't have a lot of time on the Domesday system and we all wanted a go on it.

Harjinder

help our future. I prefer to learn things like pythagoras, symmetry.

Nichola

....I think we should do more basic maths because the project was like geography not maths, but I enjoyed it and would like to do it again.

Michelle

One pupil indicated that she had learned about working in groups:

I learned that working in a group you have to work together and do the same work and make sure you can do it or you are letting your group and yourself down.

Stephanie

Several of the group commented on the better than anticipated end result for the display. This was quite impressive and was mounted near to the school entrance.

4.3.4 POST-TRIAL PUPIL INTERVIEWS

At the end of the trial period interviews were conducted with two of the groups of pupils. The responses of the first group to working in groups were positive, they contrasted this with normal practice in mathematics lessons and expressed a preference for working in this way:

BH	*How did you feel about working together as a group?*
PUPILS	*OK, we enjoyed it.*
BH	*You enjoyed it? Do you normally work together like that in maths?*
PUPILS	*No.*
BH	*If you were given a choice how would you prefer to work?*
PUPILS	*With somebody.*
BH	*One or two? How many do you think makes a good group?*
PUPILS	*Two to about four.*
BH	*Two to four - right.*
BH	*Right. Did you fall out - did you disagree about anything?*

BH	*No - you got on well. Did you manage to actually help each other at any stage? Do any of you recall being able to help somebody else?*
PUPIL	*We all helped each other really.*
BH	*All? Throughout?*
PUPILS	*Yes.*

The second group were also positive about working in groups although their experience had been less successful:

BH	*How did you feel about working together as a group?*
PUPIL	*We had a few arguments.*
BH	*What did you argue about?*
PUPILS	*Who had done all the work. And who was doing what.*
BH	*Who was arguing with who then?*
PUPILS	...
BH	*So you two thought you did all the work or not?*
PUPIL	*No - he messed it up.*
BH	*Tell me what happened then.*
PUPIL	*Well we were doing this plan and he had coloured it in and there wasn't much left.*
BH	*So what did you then do?*
PUPIL	*Argued.*
BH	*What did you decide to do?*
PUPIL	*We all left it.*
BH	*Would you like to work together as a group again? Do you think you would get on better this time.*
PUPILS	*Yes.*

The first group also commented upon learning styles and also on the teacher's role comparing and contrasting these with normal practice:

BH	*What sort of thing would you enjoy doing as a matter of normal lessons. Is it what you do or how you do it that is important?*
PUPIL	*How you do it really.*

	looking back on some of your maths lessons. What is it that makes it something not to look forward to?
PUPIL	*Fractions.*
BH	*Why fractions?*
PUPIL	*It always seems to drag on. You just seem to be doing one thing after another for ages.*
BH	*And is it difficult to understand as well or is it just the fact that it goes on and on.*
PUPIL	*Just the fact that it goes on and on. It goes on for ages.*
BH	*When you were using Maths 2000 - did Mr D seem the same to you - was his role the same as usual.*
PUPIL	*No - he had less to do with what you were doing.*
BH	*And how did you feel about that?*
PUPIL	*It was better.*

4.3.5 VIDEO RECORDING

Some video recording of small groups working with the IV system was undertaken. However the level of verbal interaction with each other whilst working at the system was not very high. Most of the groups did not get any further than the suggested system-based tasks, which had really been envisaged as introductory familiarisation activities. In the event, these activities took longer than anticipated and also the time restrictions on the pupils significantly limited what might be achieved. In addition, some video recording of the whole class situation was conducted. This conveyed much of the positive atmosphere of the classroom which has been referred to previously and also the collaborative mode of working. However it failed to illuminate individual interactions, mainly due to the technical limitations of the sound recording equipment. For these reasons, no attempt was made to transcribe this data.

4.4.0 INITIAL FINDINGS

On reflection it seems clear that a genuine misunderstanding did occur in relation to the aims of this project. The Head of Department was enthusiastic for the school to become involved in the project but did not himself. Subsequent developments led to a situation evolving where a set of twin aims developed which were never explicitly stated.

In spite of these difficulties and misunderstandings the project could be seen to be successful in terms of a staff development exercise and also in terms of setting up effective collaborative group work in the classroom situation. As the former had not been central to my aims however, I had not planned any monitoring of this aspect of the development.

One issue to emerge from this aspect of the project however was the crucial importance of the role of the teacher. It was clear that I had made assumptions about the philosophy and teaching style of the teacher with whom I was working which proved to be inaccurate, at the outset of the project at least. I had assumed that I would be working with a teacher who would be attracted to the philosophy of the project as I had outlined it in the first instance and who at least had a commitment to developing his or her practice in this direction. In fact, what I encountered was quite a degree of scepticism and considerable resistance to changing practice in the initial stages of the classroom trials. However the structure of the materials and the inevitable organisation of the classes into groups meant that a change of teaching style was made, however reluctantly in the early stages. A positive and quite promising development was the extent to which the class teacher adapted to this style of working and the degree of enthusiasm that was generated for the project as a result. His attitude towards the project in general certainly turned from being relatively sceptical and negative to one which was far more open and positive.

A further issue was the relatively superficial view I had got of the school in my time as a visitor there. I had concentrated my efforts on observing the particular class but it was clear that I lacked a perspective on the wider school and individual department. On reflection it was clear that this situation had been allowed to arise due to my relative ignorance of the school and the staff. The main reason for choosing the school had been because the staff had access to the technology. This strategy was reviewed teachers who I knew to be progressive in their thinking and practice and to arrange, somehow, for them to have access to the technology.

A further very strong and lasting impression was of the positive response of the pupils to the group work strategy. The pupils were certainly very positive in terms of their attitude towards this style of teaching and learning. However it was not clear whether this was due to the nature of group work itself or whether it was simply a response to the change from the normal dull classroom routine.

Clearly the preparatory organisation and production of the materials were of central importance in establishing the conditions in which such collaboration could take place. The model and style of the tasks contained within these materials may go some way towards answering some of the questions raised by Eraut and Hoyles (1989) and referred to previously in Chapter 3. In particular these tasks illuminate some possible approaches to task design for both computer- and non-computer-based activities and also help to begin to identify some criteria for task design and group management for the establishment of effective groupwork. The materials were designed with a common starting point which offered differentiation in terms of outcome together with a range of subsequent similarly designed activities for small groups. The order in which these activities might be attempted was flexible with only one involving the use of the IV system. The latter aspect was a response to the practical limitation of having only one IV system available. In terms of task design this varied to some extent, with some having features of practical problem solving activities e.g. "How can you measure the height of a tree?" to more open ended tasks involving the formulation of questions to ask of the data once they had become familiar with the structure and contents of the videodisc. Each task was designed as a group activity and the groups in general demonstrated some inclination towards negotiation, division of labour and collaboration. This finding is supported by Bennett and Dunn (1989) who noted that where a demand for co-operation was made by the teacher, co-operative endeavour and on-task behaviour increased to a high level.

The use of the IV system was a further motivating factor with several pupils referring to the use of "the computer" when explaining their reasons for enjoying the work in general. However there were problems associated with some groups in feeling that they did not have enough time using the system. This aspect which was also apparent through the use of video recording which highlighted the relatively low levels of interaction. Although the materials were designed to introduce the pupils to a limited range of the software options available, the time needed to achieve this was clearly greater than that available during these trials. None of the pupils achieved sufficient competence with the system, in the time available, to fully explore the software and to begin to pose their own questions. The relative complexity of the software interface was certainly a barrier to progress and clearly there was a need for significantly more time at the system, in order for the pupils to become proficient in using the software. As a result of this experience a major aim of Cycle 2 was to ensure that some pupils at least had a more significant amount of time using the computer system.

5.0.0 CYCLE 2: CROSS-CURRICULAR USE OF INTERACTIVE VIDEO IN SCHOOLS

The field work for this part of the study took place prior to Cycle 2 classroom trials. The data collection was facilitated through involvement as Field Officer for the Interactive Video in Education Awareness Project (IVIE) from May 1988 until May 1989. This role provided the opportunity for in-depth work with schools across a range of curriculum areas and also provided access to the reports of other Field Officers from across the country. This aspect of the study was essentially a period of reconnaissance in Cycle 2, which focussed upon the use of Interactive Video in schools, prior to further classroom action.

5.1.0 ROLE OF FIELD OFFICER

Following the Interactive Video in Schools (IVIS) Project, funding was made available to provide every LEA and Teacher Education Institution in the country with an IV system and software. On completion of the IVIS Project in May 1988 the role of Field Officer was undertaken jointly with a colleague for two terms initially, being responsible for an area which covered most of the North West, North and South Yorkshire and Humberside. A team of eight Field Officers together with the Project Co-ordinator covered the whole of England and Wales. The working brief involved assisting those receiving the systems and software for the first time, and also working with the established IVIS schools in the area. These schools had been involved in the IVIS Project for between two years and six months.

5.2.0 THE SOFTWARE

It soon became apparent that there were many problems associated with the management and organisation of the project. Eight software packages were due to be available, of which four were either as yet unavailable or had such unreliable software as to render them useless. Of the four remaining discs, two were provided with software allowing selections to be made via menus. These utilised authoring software packages which proved to be inaccessible useable resources for the classroom. These were the Modern Languages disc *Siville* and the Personal and Social Education disc *Challenges*. There was also considerable adverse reaction from users to the style of some of the packages. In particular the Maths and Science discs, which were only available as incomplete or unreliable versions, were seen to be too didactic and structured.

A further major problem which also became apparent was that no software had been successfully developed for one of the hardware platforms at all. This problem was not resolved, with the result that a large number of users received systems and video discs for which the software never became available. In addition to these problems resulting from the IVIS Project, the IVIE Project generated new ones, which were mainly associated with delays in the delivery of systems and a subsequent complete lack of technical support in getting these set up. As a result of these difficulties, few recipients of hardware and software under the IVIE Project were in a position to develop its use and we were able to concentrate our efforts on working with those schools which had been involved with the IVIS Project for some time. In the meantime the availability of the Field Officers was made known to all IVIE recipients and responses to calls for help were made as these were received.

5.3.0 PROJECT SCHOOLS

There were eight IVIS schools with which to work and the picture in each was almost universally one of frustration bordering upon despair. Most of the difficulties that had been experienced resulted from technical problems associated with hardware or from unreliable software, combined with an almost complete lack of any support. Hence assistance was gratefully received and much progress was made in overcoming technical difficulties. This involved simply collecting outstanding items of equipment, which had either never been delivered or had gone for repair and never been returned. In other cases it was necessary to provide up to date and robust versions of the software and in others it was a case of plugging in connections the correct way around! There were also many instances of the computers delivery. Few of the problems required very high levels of technical skill or knowledge and it was more a case someone devoting their time and energy to solving the problems. Where technical difficulties of a more difficult nature did arise, further technical assistance was available by telephone. Once teachers were assisted in overcoming such technical difficulties, high levels of interest in exploring the potential of some of the software packages soon became apparent.

After the initial IVIE workshops had been completed the Environmental Studies package became available. This included the authoring package *Opensoft* which proved to be a very user-friendly and powerful piece of software, which was accessible not only to teachers but also to pupils. The response to this software was most positive, but awareness of its potential remained limited to just a few schools. This was a pattern which was repeated across the country. There was a strong belief, on the part of the Field Officers involved with IVIE, that a real impact could have been made if funding and support had continued for a further period of time, but this proved not to be the case.

5.4.0 DATA COLLECTION

Despite these problems and difficulties there were examples of the successful use of IV at this time and case studies of good practice are reported on. These are drawn from the reports of the Field Officers throughout the UK which were compiled between May 1988 and May 1989. These reports were based on schools in which Interactive Video had been used successfully. There were many examples of disappointment and frustration but the value of these selected case studies lies in the fact that they are examples of the successful use of Interactive Video in the classroom situation. They were selected initially by the Field Officers and further selection was then made for the purposes of this study. In considering these case studies, the important issues to emerge have been highlighted and are discussed in the following section.

5.5.0 ANALYSIS OF IV CASE DATA

There are a number of issues which are common to several of these cases and which proved to be resonant with the experience of Cycle 1 classroom trials. These are considered in turn:

5.5.1 LEARNING STYLES

One feature of a number of these case studies is the evident flexibility in teaching and learning styles. Evidence is provided of the use of the technology to promote whole-class discussion as an initial stimulus to classroom activity, with considerable evidence of small group work on the part of pupils subsequently. Some aspects of this were clearly novel as one of the teachers from Ellison Primary School clearly indicated:

> *Although most of our teaching is based on group teaching and discussion, producing one piece of work from the group was new, and they had to learn to organise this. The results are pleasing and much better than I anticipated.*

This case lends more evidence to the findings of Yeomans (1983) and Bennett et al (1984) that what teachers commonly describe as group work is, in fact, most frequently simply an organisational arrangement with pupils sitting together as a group with pupils working on individual tasks. In this case, reference is made explicitly to the way in which the use of the system proved to be a catalyst for collaborative group work. Similar clear evidence of group work is provided in the reports from the two curriculum areas highlighted at Oldmachar Academy and also in the report from Eggbuckland School. This evidence also supported that from the experience in the Cycle 1 classroom trials.

5.5.2 THE ROLE OF THE TEACHER

The importance of the role of the teacher attracted explicit comment from the staff of Ellison Primary School

> *The teachers have seen their role as one of manager, discussion leader, and helping the groups to organise their tasks.*

This role which involves managing, promoting discussion and helping groups to organise tasks is not explicitly commented upon in the case studies from Oldmachar Academy but is implicit in the descriptions of the learning experiences outlined. However it is evident from these accounts that the Development Officer herself was in the role of the teacher for much of the time. The crucial importance of the role of the teacher reinforced the initial findings from Cycle 1 classroom trials.

5.5.3 SUPPORT FOR PROFESSIONAL DEVELOPMENT

It is clear that the Development Officer who worked with Oldmachar Academy played a leading role and she did make explicit reference to the teachers' need for *a great deal of help and support*. She describes how she prepared classroom resources, in the form of video sequences and worksheets, for both groups with which she worked in the classroom situation. This role was similar that undertaken as participant observer in Cycle 1 classroom trials, apart from the fact that on the basis of these accounts, it appears that, in this study, the classroom teacher was involved to a greater extent. Similar support was obviously available to the staff of Knowle Hill School, with the staff specifying their requirements to the Field Officer. The staff of Ellison Primary School appeared to be more independent of external support and it is perhaps significant that reference is made to the involvement of the school's IT Coordinator.

5.5.4 MOTIVATION

It is clear from these case studies that there is considerable potential in the use of Interactive Video for motivating the interest and enthusiasm of children. This would seem to be related to the power of the visual medium and is consistent with the experience from Cycle 1 trials, even though this was restricted to the use of still as opposed to moving images. It was also noted to have had a positive impact upon the achievement of low attainers at Oldmachar Academy.

5.6.0 SUMMARY

These case studies highlight a number of important features of the school and classroom situation where the successful use of Interactive Video had been identified. These features can be summarised as follows:

- flexible learning styles and the use of small group work
- the teacher as facilitator in managing and promoting discussion and in helping groups to organise tasks
- support for professional development
- evidence of high levels of pupil motivation

The first two features relate to issues to do with teaching and learning styles. The third feature relates to the need to support teachers in developing the use of Interactive Video. Several of the examples involved the use of external support but in one school the IT Coordinator was closely involved in the development. Some level of support was evident in each of the case studies. Having overcome pedagogical and technological barriers, a feature of each case study was the high level of interest and enthusiasm demonstrated by the pupils.

6.0.0 CYCLE 2: CLASSROOM TRIALS AT SCHOOL B

Cycle 2 classroom trials took place in June 1990 at School B which was chosen on the basis of some knowledge of the teaching staff within the Mathematics Department. The criteria for selecting this particular school were based upon my experience in Cycle 1. The intention was to work with teachers who I knew would be in sympathy with the overall approach of the project in general. Access to or previous experience with the technology was not a priority in terms of selection. In fact I knew the staff of the department to be generally progressive in their thinking and practice, and a working relationship was well established as a result of previous regular student placements in the school. The school had only recently been formed from the amalgamation of two schools and the Mathematics Department was staffed by an experienced team of teachers. The staff included two former Heads of Department, of whom one had now taken on the role of IT coordinator, in addition to an Assistant Headteacher who was also very involved within the department. My approaches to work with the school were immediately welcomed and arrangements soon made to work with two classes. Given the strength and experience of the staff, it was surprising how little use was then being made of computers in general within mathematics. This was readily acknowledged and action to begin to remedy this situation was seen to be a priority, with the result that this project was particularly welcomed.

The school did not have access to an IV system but, after a considerable number of enquiries, I was able to trace the Domesday system, belonging to the LEA, which did not seem to be being used very extensively and arrange for this to be placed in the trialling school. This was a welcome bonus for the school and the IT Coordinator was especially enthusiastic about this development. It did not however prove to be possible to work with one of his own mathematics classes.

Arrangements were made to work with two Year 9 classes for a two week period. One class, 3(5), was a top "ability" group being taught by the Head of Department and the other, 3(3), was a below average "ability" group being taught by the Second in Department and another teacher for one lesson a week. The classroom materials were substantially the same as those used for Cycle 1, apart from minor amendments and general improvements to layout and presentation. My role was similar to that in Cycle 1, in that I intended to work with small groups within the classroom and to focus my attention on the use of the computer system, in addition to general classroom observation.

6.2.0 TRIALLING

The first lesson with 3(3) involved the pupils being organised into groups and working outdoors on the initial practical activities. This lesson was not long enough to carry out all the tasks, with the result that the activities continued into a second lesson. The class teacher reported a high level of motivation for these tasks, from a group that was not normally very highly motivated or interested, which confirmed my initial impressions of the group. During this stage with the group, most of my time was spent supervising and assisting with the practical activities outdoors. Generally there was a high level of involvement in the tasks. Early into the second lesson most of the pupils were able to return to the classroom, with results from completed activities. By the third lesson all the pupils were working on their results and it was at this point that groups were introduced to the system in turn.

I attempted to give an overview of the system, provide as much hands-on experience as possible and encourage the pupils to pursue their own questions as far as possible. As a result I tended to work more intensively and for longer with each group initially, than in Cycle 1. This had the effect of giving each group more confidence to use the system independently but it took longer to provide each group with a turn. Since there were only 18 pupils in the class, however, each group was introduced to the system within two lessons.

There was no doubt that all the pupils found working at the computer to be motivating and were eager to take their turn in using it. It soon became apparent however that some pupils had considerable difficulty in maintaining their interest in and concentration on the other tasks, going on in the classroom at the same time. This called for considerable encouragement from the class teacher, for some pupils to remain on task at times. In a subsequent lesson, the class teacher was unable to be present and I chose to take the class on my own. This was a useful experience in that it highlighted the difficulties that would be faced by most teachers, on a day to day basis, in trying to make use of the system in this way. It proved to be difficult but manageable, mainly as a result of the fact that the pupils had by now developed sufficient confidence and expertise with the system to use it on a relatively independent basis. This situation would have been far more difficult to manage, had I been also trying work intensively with groups at the system at the same time.

At least one group of pupils became very confident in their use of the computer becoming highly motivated on discovering that they need not confine their searches to *Trees* and could in fact find information and pictures on almost any topic that they could think of. At this stage the relevance to mathematics became obscure and their motivation to return to the other related tasks on the theme of *Trees* was much reduced. They did however pursue their exploration of the system outside the normal class times.

The class teacher who had been very involved with the group at the start, seemed to lose touch to an extent with the progress of the group. His absence was due to course attendance on one day, which preceded that on which the second teacher taught the class. This meant that two lessons took place in his absence. As a result, his awareness of the use of the IV system seemed to remain quite limited and in some ways he was detached from the pupils' activities whilst using the system.

their course based upon the SMP Yellow Series. Although I was unable to be present at the start of this series of lessons, I did get a comprehensive verbal account of their progress from the class teacher. The teacher, who was also the Head of Department, was clearly interested in the thematic approach and the emphasis upon collaborative group work in addition to the incorporation of the use of the IV system. Considerable time was spent at the start of the series of lessons in discussion of the topic of *Trees* and very little reliance seemed to be placed upon the printed materials. A brainstorming session was held on the potential areas of investigation, which led to a number of pupils wishing to pursue their investigation along the lines of topics such as acid rain, tropical rain forests etc.

It was quite clear that this class had been highly motivated by their initial activities to pursue the theme of *Trees*. It did however become apparent that most of the group had carried out many of the practical activities to find the height of trees etc. in the previous year, so these were not pursued. Given the considerable initial input by the class teacher it was some time before the pupils came to use the IV system. At this stage some were disappointed that there was little information available on their chosen topic e.g. in the case of tropical rain forests. They seemed to have been encouraged by their teacher into thinking that the data on the system was almost unlimited, and covered almost every conceivable topic. However these pupils soon directed themselves to the library and found all that they needed there. One effect of this, however, was that some pupils hardly used the IV system and in general the use of the system was much less of a feature of the learning experience for this group than had been the case with 3(3). This may account for some of the differences in pupil response which were noted at the end of the trialling period.

6.3.0 DATA COLLECTION

A similar strategy to that adopted in Cycle 1 trials was planned for Cycle 2. Feedback from several sources included pre-trial and post-trial questionnaires to pupils. The teachers agreed to keep teacher diaries in addition to ongoing discussions concerning the progress of the project. In discussions with teachers and pupils. The option of video recording was kept open but this was not chosen for a variety of reasons. The data generated in Cycle 1 by means of this had not proved to be very informative and it was not clear how the data that might be collected in Cycle 2 would differ. The lower ability class, 3(3), made considerable use of the system but not in way that was particularly mathematical. The more able group, 3(5), for reasons already outlined did not make extensive use of the system and therefore opportunities for recording these pupils working at the system were minimal. The analysis of the data collected is reported upon in the following section.

6.4.0 DATA ANALYSIS

6.4.1 TEACHER FEEDBACK

The feedback from the teachers was based upon my own notes of ongoing discussions, together with those from discussions with the staff at the conclusion of the project. Written feedback, in the form of teacher diaries, however was not forthcoming.

The response to the project as a whole was most positive on the part of both teachers who were involved. The class teacher of the lower ability group, 3(3), remarked upon the unusually high level of motivation on the part of many of the pupils in this group. This was attributed to the combined effect of the practical activity outdoors, the use of the system and also to working in groups. However it was also clear from discussion that all of these aspects were novel for this group. It was also clear that expectations, in terms of level of mathematical achievement, were generally not high.

The expectations of the more able group, 3(5), were quite different. This group was composed of highly motivated and able pupils by contrast. The class teacher confirmed that he had set the initial task to be as open as possible, in order for the pupils to decide upon their own lines of investigation. It was also clear that he had assumed far more of the system than it had been able to deliver. The scope of the data available had been assumed to be almost unlimited, which proved to be far from the case.

their chosen lines of enquiry. This was disappointing for both the teacher and the pupils, who in turn had been led to expect more. However the class teacher did recognise the way in which he had made assumptions based upon little prior knowledge, and was still interested in pursuing his interest in the system further at a future time. The effect however was to seriously restrict the activity based on the system for this class.

6.4.2 PUPIL RESPONSES

In their responses to the initial questionnaire there was a contrast between the two groups, as summarised in Table 1 below, with 45% of 3(5), which was the high ability group, reporting that they normally worked on an individual basis compared with only 6% of 3(3). There was also a difference between the levels of previous computer use with 91% of 3(5) reporting no previous use compared with 56% of 3(3).

	3(5)	3(3)
Individual work normal	45%	6%
No previous computer use	91%	56%

Table 1 *Cycle 2 pre-trial pupil questionnaire*

There were also some differences between the two groups in their responses to the post-trial questionnaire as summarised in Table 2. For example 70% of 3(5) said that they did not wish to spend any more time on the project compared with 59% of 3(3) who said that they would like to. Also 35% of 3(3) cited the use of the computer as a main reason for enjoying the work compared with only 19% of 3(5).

	3(5)	3(3)
Wish to continue project further	30%	59%
Use of computer as main reason for enjoying work	19%	35%
Rating of work as average	30%	53%

Table 2 *Cycle 2 post-trial pupil questionnaire*

The differences in emphasis and approach to the use of the computer as outlined above may account for some of these differences. The fact that 3(5) did not wish to spend any more time on the project did not appear to be for especially negative reasons. However this group was orientated towards working through the SMP Yellow course which was certainly a factor for one pupil who noted that *it was good but it wasn't relevant to what we were doing in the Y2 Book.* A smaller percentage at 30% of 3(5) rated their work as average compared with 53% of 3(3). There were no other especially marked differences between the two groups.

The combined responses of the two groups to working on the project were almost entirely positive as summarised in Table 3 but there was not the unanimity that was present in Cycle 1. Responses to working in groups were overwhelmingly positive (84%) and compared well with responses from Cycle 1 (86%). A significantly larger proportion rated their work as average (39%) compared with only 17% from Cycle 1. There was a significantly more positive response to the use of the Domesday system in Cycle 2 with 71% rating it in one of the two higher categories compared with 41% in Cycle 1. In general most of the other responses were of a similar nature with perhaps more illumination on pupils' attitude and thinking being provided through some of the individual written comments.

	Cycle 1	Cycle 2
Positive response to group work	86%	84%
Rating of work as average	17%	39%
Positive response to the use of the Domesday system	41%	71%

Table 3 *Comparison of pupil responses: Cycle 1 and Cycle 2*

Examples of ways in which pupils worked in groups:

When one of my friends in our group didn't know how to use the Domesday computer I showed her how to find the subjects they need.

Danielle

I didn't know the name of a tree so I asked a friend.

Daniel

..... help other people finish off their work - got helped by people when I couldn't work out something.

Frances

.................Our poster was a team effort.

Helen

We all helped each other.

Angela

When displaying our work I helped Joanne to organise our poster. We worked as a team and so when I needed help my friends helped me.

Lisa

I gave people in our group ideas.

Frances

I helped Rachel to find some reference books in Handsworth Library. Everyone in the group helped me to arrange our poster.

Kirsty

In my group I was helping Louise gather some information about the ages of trees. We both had to count the rings on the tree stumps. Also we had to assist each other when measuring the height of trees.

Joelle

I helped other people in my group to find a scale for their graphs. I also helped other people to work the Domesday computer correctly.

Steven

I got some help off Nadim and Adam when I was stuck.
Lee

I helped people in my group and they helped me.
Vicky

In my group we helped each other if we got stuck on something.
Matthew

I helped Lisa with her pie chart because she couldn't understand it.
Clare

These comments reflect the generally high level of collaboration that was evident from working with the classes, in spite of the fact that this was not the typical way of working in mathematics according to the pre-test questionnaire.

General reactions to work on the project TREES as a whole:

I enjoyed TREES because you could find out what you want.
Lee

With everyone working together there was lots of effort put in.
Anon

Good because we worked in groups and used the computer.
Corrie

We didn't do as much work as expected. I think this is because there was just one computer.
Steven

I think our work on TREES was good because we got on well together in the group and got quite a lot done.
Joanne

Good because I think that our poster looks attractive and well held together.
Kirsty

attitude towards group work, in addition to positive comments on the use of the computer system and also on the quality of the end result.

General reactions to using the Domesday system:

> *I liked using it a lot because it was very interesting and the picture was not blurred like normal computers.*
>
> *Daniel*

> *It was very interesting on the Domesday system. It told me a lot of information I didn't know.*
>
> *Chris*

> *I like using the computer also we could have fun looking up things besides trees.*
>
> *Angela*

> *I liked using the Domesday system because you could gather information easily and we haven't used computers this year in maths.*
>
> *Lisa*

> *I enjoyed using the system because you could retrieve information about anything.*
>
> *Simon*

> *I liked using the Domesday system but we didn't have much time on it.*
>
> *Wayne*

> *It wasn't just information and graphs. It had pictures too.*
>
> *P.*

> *I liked using the system because if you want to find out about football then you type in football and you find it.*
>
> *Lee*

> *I enjoy using the computer because we never use it in maths lessons.*
>
> *Debbie*

I enjoyed using the Domesday because you could find out a lot of information about different subjects.

Adam

I enjoyed using the system because you could find out whatever you want.

Nadim

These comments reflected a positive response to the use of the computer to retrieve information. Clearly the nature of the information was of interest to the pupils and the visual aspects of the video disc was an added factor in creating this level of interest.

General responses to what had been learned:

Whilst doing TREES .... I have learned that we are killing many species of unknown animals and plants that could be vital to our life, and how important it is to keep the rainforests.

Joelle

I have learned about how quickly the rainforests are being destroyed, how to make recycled paper ....

Frances

I learnt about the trees in our area, most popular, highest and smallest, as well as the highest, oldest tree in the world etc.

Simon

I have learned how fast trees are being pulled down and how important recycling is.

Angela

On the whole I didn't learn anything mathematical. We had done some work on finding the height of trees in the second year. I did enjoy using the Domesday system.

Helen

Whilst using the Domesday system I learned about the number of dying trees in different areas of England and Wales. I learned that we need to conserve the trees otherwise the greenhouse effect will get worse.

Steven

I learned a lot about trees. I learned about the urgency of rain forests and the pollution around us.

Kirsty

I learned how to measure the height of trees by two different ways.

Clare

I think I learned about the shortage of trees in the UK and more effort should be put into planting more. I learned that trees are a necessity to life and that everything should be done to protect them.

Matthew

How to do pie charts and other charts.

Vicky

I learned that you cannot only get letters and numbers on the computer, but you can also get pictures.

Debbie

Just how to find information reasonably quickly.

Jill

How to use the Domesday system.

Alison

I learned how to measure the girth of a tree.

P.

We learned how to find the height of trees.

Chris

I learned that any information you wanted about England and Wales was on the disc.

Daniel

I didn't know you could get that much amount of information on one disc.

Danielle

many of the pupils were quite willing to list environmental issues as legitimate learning and most of these were from the more able group. This was in contrast to Helen who remarked that she *didn't learn anything mathematical.* The role of the teacher in motivating the group and in legitimising the exploration was perhaps significant.

6.5.0 FINDINGS

The experience in Cycle 2 served to reinforce my view of the crucial importance of the role of the teacher. Having identified a strategy of targeting teachers who would be largely sympathetic to the aim of the project from the outset, this was successfully put into practice in this cycle. In fact, the enthusiasm and motivation generated by the class teacher for 3(5) did have the effect of deflecting the pupils from making as much use of the computer system as they might otherwise have done.

As with Cycle 1, there was a very positive response from pupils to working in groups with a very similar percentage being in this category on each cycle (86% for Cycle 1 compared with 84% for Cycle 2). The inclination of the pupils towards collaboration is particularly evident from their individual comments, which contain much evidence of pupils' ability to negotiate and collaborate.

The responses to using the Domesday system were generally positive with a larger proportion (71%) rating its use highly on Cycle 2 than on Cycle 1 (41%). The reasons given for enjoying the use of the system related to the nature of the information available and also to the visual aspects of the video disc. My impression in Cycle 2 was that the pupils, and especially those in 3(3), had more time on and therefore became more skilled with the system. They also became more aware of the power of the system and the range of information that was available, as the following comments, which in general were qualitatively different from Cycle 1 indicate:

> *...........also we could have fun looking up things besides trees.*
>
> *Angela*

.... you could retrieve information about anything.
Simon

................if you want to find out about football then you type in football and you find it.
Lee

.....................................you could find out whatever you want.
Nadim

These comments not only reflect an interest in the nature of the information but also a positive reaction to being able to choose that information. Another aspect of using the Domesday system which was cited by pupils was the relative ease of access to the information available on the disc. However much of the activity by pupils in 3(3) was not of a very mathematical nature. Several pupils in the class certainly developed their skills in using the system, but their enquiries were driven by their general interest in accessing information about particular topics such as football, popular music, drug addiction etc. Much of the information that was gathered was not necessarily presented in a mathematical way e.g. it was predominantly in the form of pictures or text.

Overall there was a positive response to the cross-curricular aspects of the project and it would seem that the influence of the teacher, especially with 3(5), was a significant factor in generating this level of commitment and enthusiasm.

In general the experience in Cycle 2 reinforced most of the initial findings from Cycle 1. Given that the teachers with whom I worked were at ease with classes working collaboratively in groups, I was able to observe pupils using the computer to a greater extent than in Cycle 1. This probably served to highlight the limitations of the system as much as it did to illuminate the potential.

7.0.0 CYCLE 3: EVALUATION OF *WORLD OF NUMBER* and INITIAL CLASSROOM OBSERVATION

7.1.0 INTRODUCTION

This chapter provides an account of the evaluation of the National Curriculum Council (NCC) multimedia package *World of Number* which was carried out prior to Cycle 3 classroom trials, in line with the revised objectives of this study. The initial evaluation of the materials was undertaken in the light of the original project specification from the NCC. The process began with a study of the support materials followed by a systematic viewing of the contents of the discs. Reflections were recorded in an ongoing diary. Once this was underway the process was complemented by an ongoing review of the relevant literature related to the NCC project at that time. The final stages of this phase involved semi-structured interviews with teachers involved in using the materials and school visits for the purpose of classroom observation.

The package is first outlined, followed by a summary of the original specification from the NCC. The results of the initial evaluation, background reading, interviews with teachers and classroom observation then follow.

7.2.0 OUTLINE OF THE PACKAGE

The package was initially developed on laser disc and consisted of fifteen units contained on three video discs together with a folder of printed support materials. The materials were broadly aimed at the secondary mathematics classroom, at Key Stages 3 and 4 of the National Curriculum. Subsequently five of the units were transferred to four CD ROM discs and the support materials were stored on these discs in electronic form. Thus there was an overlap in terms of the content of both versions of the package although the organisation of the materials was different. The initial evaluation was carried out using the laser disc system, whilst the material development and classroom trialling phases involved the use of both versions. The units are outlined briefly in turn:

7.2.1 Number Games

Number Games is a collection of problem starters presented by a group of secondary school students. No solutions are offered but the students can be observed discussing the problems. The problems are concerned with number patterns, symbolisation and strategic skills and are typically seen to occupy a double lesson. It is envisaged, by the designers, to be suitable for individual, small group or whole class working.

7.2.2 React!

This unit involves the user in testing reaction times in response to two scenarios. The first of these involves trying to catch a falling £20 note and the second falling plates from a wall. The user controls one or two hands on the screen through keyboard commands and the reaction times are displayed and recorded. The data which is collected is available for statistical analysis. The authors envisage that it could provide small group or whole class work over several lessons.

7.2.3 Perspectives

This unit is made up of three sections which share a common element in that the screen is divided into four windows that enables the user to view the information from four different perspectives. The windows contain moving video, still graphics and data, any of which the user can access and choose to enlarge. The first section is entitled *Alcohol* and involves students in considering and comparing data on alcohol levels in the blood. The second section is called *Running, Jumping and Flying* in which the user can select an example of people, animals or objects in motion and select an appropriate graph to match the motion. When the correct choice is made, the graphs are mapped out in step with the motion being shown. The third section is *Cube Towers* which presents the user with models made from Multilink cubes. The tasks involve the selection of the correct plans and elevations to match each of the models. This unit is seen, by the authors, to provide activities suitable for small group and whole class work for one lesson or longer.

7.2.4 Who Stole the Decimal Point?

Who Stole the Decimal Point? is a simulation game which involves students in an adventure which requires a series of mathematical problems to be solved in order to complete the story. The story begins with a group of teenagers who discover a computer virus that corrupts any calculations involving a decimal point. The source of the virus is traced back to a country house where the group encounters a character named Count Integer who locks them in a room. In order to unlock the door, the user is required to explore the house and to solve a range of mathematical problems. There are twelve such problems together with seven further problem starters which are not directly related to unlocking the door. Activities away from the machine are encouraged and it is seen, by the designers, to offer the potential for small group and whole class work over many weeks.

7.2.5 Ways of Calculating

This unit provides a choice of mathematical problems to solve with the option for the user to observe how four other students solved the problems in different ways. The aim is to encourage students to reflect on the ways in which they calculate and to develop an awareness of a range of approaches. It is suggested in the documentation that each problem might occupy several lessons for individual or small group work using the printed materials, followed by whole class discussion about the video sequences.

7.2.6 Human Mosaics

The *Human Mosaics* unit includes examples of professional displays from the Seoul Olympics in 1988, a television commercial and also some examples of work done by a school. The aim of this unit is that such sequences be planned on a smaller scale in the classroom. The designs themselves are formed by tiles with a limited number of positions which change over time. These factors can be defined numerically, leading to a range of number-based activities involving co-ordinates, estimation and number patterns including multiples and square, triangular, prime and Fibonacci numbers. It is suggested, by the authors, that this unit might provide extended group activity over several weeks.

Students are asked to consider issues and factors which affect their choice of jeans in this unit. The resulting mathematical activity involves data handling, estimation and ratio and is considered, by the designers, to be suitable for individuals and small groups over several lessons.

7.2.8 Powers of Ten

This unit is made up of a well known film which was made for IBM in 1977/78 to show the relative size of objects in the universe. The film zooms out into the universe and back into the atomic structure of matter. The *Toolbox* is available and opportunities are presented for work on very large and very small numbers, standard form and units of measurement. The authors suggest that it is suitable for whole class or small group work.

7.2.9 Numerical Labyrinth

This unit is described as a powerful maze-designing program which has been used by students over a wide ability range. It is suggested that mathematics arises naturally through designing a maze and from charting other people's mazes. The maze itself generates activities with coordinates, compass directions and other spatial descriptors. It is suggested, by the authors, that it could provide small group work over several lessons.

7.2.10 Life Doesn't Run Smoothly

Three short drama scenes which focus on typical situations that can occur in students' lives make up this unit. It is suggested, in the documentation, that each drama might occupy a whole class for a lesson. It involves the using and applying of mathematics, especially in relation to the use of money, timetables and arithmetic calculations.

7.2.11 Short Tasks

Short Tasks provides a number of explicitly stated short tasks which, it is suggested, might best be used at the start and end of lessons, and for homework. The tasks cover number sequences, aspects of arithmetic and estimation. Although the problems are short to state, the authors suggest that some might lead to extended work for small groups and whole classes.

7.2.12 Mechanisms and Linkages

Mechanisms and Linkages involves a film of time-lapsed photographs over which the user can gain single frame control. Together with the *Toolbox* software, opportunities are opened up for the investigation of the linkages leading to work on ratio and locus. It is suggested, in the documentation, that this unit provides for at least one lesson with a whole class as an introduction, followed up by small group work.

7.2.13 Picture Gallery

Picture Gallery contains over 700 still pictures which are intended for use with the *Toolbox* software leading to mathematical activity involving angle, ratio, scale, percentages and estimation. Sections of this unit are suggested, by the authors, to be suitable for use by small groups for a single lesson.

7.2.14 Challenge

In this unit simple arithmetical problems are displayed using a mixture of video and computer graphics. After a preset time interval, the solution is then displayed. The type of question, level of difficulty and the time interval can all be controlled by the user. Unlike traditional drill software, there is no facility for entering the answer at the keyboard and it is suggested that, by this strategy, the range of styles of use is greatly increased. The intention of the designers was to get students to share and compare strategies for doing arithmetic and they suggest that it is suitable for use by small groups for part of a lesson.

7.2.15 On the Move

The aim of this unit is to exploit the possibilities for number activities with moving images. A series of short video clips appear in three sections which the students are able to explore with the facilities of the *Toolbox* and single frame control. The *Toolbox* enables points to be marked on the screen, straight lines to be drawn, distances to be measured on the screen and angles to be measured. The authors suggest that small groups might work on one clip for a single lesson.

The video disc package is supported by a ring binder of materials which is made up of one section of general instructions together with a very substantial section of student activity worksheets and teachers' notes. The equivalent materials are stored electronically on the CD ROM version and can be printed off as required by the user. The authors describe the package as a "flexible resource" and emphasise the following features:

- a collection of support materials for the teacher to choose from
- suitable for use with a wide range of teaching styles
- stimulating starting points for a wealth of mathematics
- no particular teaching or learning approaches are dictated
- any given item can be used with different content areas and levels of attainment (in the National Curriculum)
- the audio-visual "world" of the package aims to be that of the student in school
- in many of the units it is up to the user to set specific tasks, so that the package can be used to fit different teaching plans

7.3.0 ORIGINAL PROJECT SPECIFICATION

The original project specification (NCC, 1989) outlined the nature of the proposed discs. The primary focus was upon the programmes of study related to the Attainment Targets involving number. In addition the specification outlined the need to design the materials to take account of the uses and applications of number through the appropriate Attainment Targets, which were subsequently reduced to a single attainment target concerned with Using and Applying Mathematics. It was recognised that aspects of number would arise in other Attainment Targets and developers were further encouraged to consider the cross-curricular applications of mathematics. Importance was also attached to the capability of the materials in providing support to teachers for the purposes of diagnostic assessment.

The desired aims of the materials were to:

- help pupils to develop their conceptual understanding and skills in

- help pupils to have a positive attitude to work with number
- help pupils progress through the levels
- encourage both independent investigation and similar work in small groups
- stimulate and engage the natural curiosity of pupils through imaginative use of the medium
- illustrate the use of number in familiar everyday situations
- demonstrate the power of mathematics as a tool and means of communication

Additionally, the materials were aimed at providing support for teachers, including those who were less well qualified or who found number difficult to teach. Further guidance emphasised that the materials should also:

- reflect good practice in mathematics and add value to the work in the classroom
- promote the productive use of other resources
- present a level of mathematical challenge appropriate to the age of the pupils

7.4.0 INITIAL EVALUATION OF THE MATERIALS

The evaluation began with a consideration of the previews of each unit in order to get an overview of the contents of the discs. Very early impressions were of a high level of organisational complexity of the package as a whole combined with a high level of technological complexity. The latter was not experienced as a particular problem for the purposes of the evaluation but the impression was formed that the degree of technical sophistication required to operate the system would be a significant barrier for many teachers. The result of the initial evaluation of each unit is reported on as follows:

7.4.1 Number Games

In this unit several problems are presented which, although not original, are all good starters for mathematical activity. These are presented in the context of a small and well ordered group of students. An initial thought reference to teaching and learning styles was found in the documentation but all the guidance appeared to relate directly to the computer-based activities. No discernible guidance was found relating to strategies for managing the classroom as a whole. In the introduction it is suggested that all the activities are suitable for pairs of students, some for individuals and others for larger groups. It is also noted that all the problems could be posed by a "straight worksheet" or by the teacher to the group. The suggested advantages of the video are that the students can replay the extracts at will and that the teacher is "freed to act as observer and counsellor". This minimalist view of the role of the teacher is further emphasised by the concluding comment in this section which is that: "Your best ploy may be to move quickly to the stock cupboard and let them get on with it!"

An early effort was made to get a sense of the relationship between the software and the printed materials. The sense of complexity with the printed materials was especially great at this initial stage. Also there was a strong impression of the relative unattractiveness of the print materials, which consisted generally of quite dense black-on-white text. This was in stark contrast to the quality of the visual images on the computer screen. The organisation of the file was also a source of extreme inconvenience. The pages are arranged sideways on, with two A5 sheets side by side. However on turning over each page the following page is found to be upside down, which was even more problematic given the bulk of the file and the often restricted amount of space near to the computer screen.

In reflecting upon the initial evaluation of the *Number Games* unit, I made reference to the widely cited system of classifying educational software devised by Kemmis et al (1977) which described four educational paradigms into which educational software could be placed, which need not be mutually exclusive. These are the:

- *instructional* paradigm - programmed learning/drill and practice
- *revelatory* paradigm - the learner makes discoveries using simulations

models

- *emancipatory* paradigm - using the computer as a tool to manipulate numbers or text, so freeing the user to concentrate on the learning experience

However, on further reflection, it became apparent that *Number Games* could not easily be placed in any of these categories. This is due to the fact that in general the unit consists of a series of stimulus video clips, providing motivation for investigatory number activities. The designers readily acknowledge that the activities could well be posed using printed material or simply by the teacher to the whole group. Accepting that the video does provide a valuable additional element, the link with a powerful computer system does not appear to be an essential factor. Hence many of the units did not fit into any of these categories and were subsequently classed simply as *stimulus video.*

Given the model whereby all the activities are suitable for pairs of students, some for individuals and others for larger groups, the nature of the envisaged classroom environment is not clear . The role of the teacher is also very unclear. In fact all the activities seem to be ideally suited for whole class introductions by the teacher. One scenario would be for the video to take over this function of the teacher's role. However the advantages of such an approach are not obvious. One immediate major disadvantage would be presented by the small size of the screen. If the mode of use is to be small groups the questions that arise relate to how many activities might be in use at any one time, how the activities might be staggered and how the whole class might function whilst some groups were still awaiting their turn. The support materials are not illuminating on these questions.

Subsequently it was found that Cutler (1993) shared some of these reservations about the package. In particular he raises questions about the appropriateness of the medium: "In some instances it is difficult to see that there is any merit in having the task introduced on film ... rather than in the there are opportunities to interact with the computer. In this case a set of lights can be operated by two switches, with the problem being to switch on all the lights, having first worked out the rules by which the lights are governed. He notes that: "There is something very satisfying in having the screen verify that one's theory is correct" and also observes further that there are rather too many cases throughout the package where there is no feedback or indication of the sort of outcome that might be expected.

In response to Cutler's first point it would seem that one scenario from the *Number Games* unit in fact could be categorised under the the *revelatory* paradigm. However the mixture of styles within the package and the very wide range of materials led to the early conclusion that no particular dominant category was likely to emerge in general from this system of classification. In response to the second point relating to the general lack of feedback provided by the system, this view was also formed early in the evaluation process. This general lack of feedback is particularly surprising given the emphasis on diagnostic assessment in the original project specification.

7.4.2 React!

This unit involves an entertaining activity in testing reaction times against the computer. In this sense the computer is in an interactive mode with the user. However the user is left with a list of reaction times but the computer is not programmed to analyse or display the resulting data. This is disappointing given the not unreasonable expectation of rather more from a powerful computer system. This view is also shared by Cutler who notes further that the user is asked to calculate mean and median times but that no check is provided by the software. He concludes with a view, which can be supported from this evaluation, that: "This seems to be one instance where the power of the computer has not been put to sensible use." The printed materials do however provide a wealth of ideas for further investigation.

7.4.3 Perspectives

The first section of *Perspectives* is on the theme of alcohol, health and screens in which information relating to alcohol consumption is presented, followed by some written instructions to carry out some calculations. No use is made of the moving video capabilities of the system nor of the audio channel. There appears to be no advantage over colour presentation by means of printed materials. The second sequence involves an actress, in a light hearted way, setting the scene to the context of alcohol and its effects. This scene is then also followed up by a written task on screen. The video is used entirely for the purpose of setting the scene in what is, in fact, a somewhat contrived way. The third task involves the presentation of a formula together with some graphically presented information. Once again this is followed by some written instructions related to the task which does not involve the use of video or sound track. The fourth activity involves the use of several closed questions with no facility for feedback from the system. The fifth activity is introduced by means of a humorous sketch by the comedian Rowan Atkinson, who outlines some funny ways of remembering the safe number of units of alcohol which can be consumed per week. The students are encouraged to devise their own funny ways to remember these, and other significant numbers, in the wide range of accompanying printed materials which support this unit as a whole. Although amusing in itself, this section of the unit, together with the scene involving the actress, does feel incongruous when viewed as a part of the package as a whole. The final activity involves monitoring the drinking habits of TV characters over the period of a week. Overall impressions were of a number of good starters for mathematical activity, which would require a teacher to structure carefully, but for which the use of the video element was not an essential item.

The second section of *Perspectives* is *Running, Jumping and Flying* which has several video clips of athletes in action at the Seoul Olympics in 1988 together with some further examples of objects or animals in motion. In one section of the split screen, the motion can be observed and this can be run in the full screen if desired. The user can then select from a set of given axes in another section of the screen and then from a selection of possible graph lines in another quarter of the screen. These are overlayed in the final screen with the graph overlayed in step with the motion. Although the arrangement of the screen environment is not that simple, this section seems to make particularly effective use of the video element in a way that could not be reproduced easily by any other medium. The feedback is a positive feature although it provides possible scope for unthinking use by the user. This section of the unit clearly fits into the revelatory paradigm of software use.

The third section of *Perspectives* is concerned with selecting the correct plans and elevations to match a range of models made from Multilink cubes. Once a choice has been made, this can be tested and, if correct, the system shows a full screen view of the tower which can be rotated through different angles. The feedback element in particular seems to offer something relatively unique but this could, in fact, be offered as effectively by means of computer graphics. This section of the unit can also be seen to fit into the revelatory paradigm of software use.

7.4.4 Who Stole the Decimal Point?

The first impression on viewing *Who Stole the Decimal Point?* was of the most immediately accessible unit of the package. The context is set quite powerfully using student actors, together with the soundtrack, to draw the user in to an adventure scenario. Once familiar with the control software, the user is free to explore the house in which the adventure is set by means of a "surrogate walk". Therefore all users are able to enter into the adventure and to engage in an exploration of the house regardless of their level of mathematical ability. The mathematical problems presented are very variable in terms of both their level of difficulty and also in terms of their level of interactivity directly with the system. For example, some problems, such as those involving a shopping bill and a cube, are best conducted away from the system once the problem has been set. Others, such as *Dress*, *Boat* and *Bells* need to be pursued at the system and are the only mathematical aspects which utilise the interactive potential of the system. Suggestions are made regarding styles of use including one allowing small groups of between two and four students to work on the quite unrealistic in most classroom situations, with only one system in the room. *Bells* can be considered to be in the revelatory category but none of the other elements of this unit can be categorised as educational software. Therefore they have been classed simply as stimulus video.

7.4.5 Ways of Calculating

The particular feature offered by *Ways of Calculating* that is initially most apparent is the facility for allowing the user to replay the discussions of the students, on the video, involved in solving mathematical problems. The designers suggest that the class works on the problems in advance of watching the video, using the printed support materials, and then use this as a focus for whole class discussion. Given that control of the system will be invariably with the teacher, it would seem that this activity could be carried out as effectively using a standard video tape player. A disadvantage, as with any whole class activity in this context, would be the small size of the screen that would be generally available.

7.4.6 Human Mosaics

This unit is essentially a series of stimulus video clips in the style of several of the other units. No interactivity is required with the computer although some melody lines are included on the audio track for student use in devising their own routines. It seems that this unit could very easily be delivered using standard video and audio tape.

7.4.7 Jeans

Jeans appears to be very similar in style to *Human Mosaics,* with the video being used as a stimulus for class discussion and no interactivity required. Much of the work related to this unit would in fact be generated by the use of the substantial quantity of follow-up material. The mathematical activity so generated would be very appropriate but the use of a powerful computer system linked to video does not seem to be an essential element.

7.4.8 Powers of Ten

On viewing the film *Powers of Ten* the impact was very powerful and there

Toolbox. However considerable planning of the whole classroom would seem to be required and individual groups would require some intensive periods of time at the system. Potentially this unit could be placed in the revelatory category.

7.4.9 Labyrinth

The initial reaction to *Labyrinth* was of a very open-ended resource with rich potential. However there was an almost immediate question of how it might be used in a classroom situation. Group work is suggested but it would seem that intensive long term use would be required by individual groups leading to questions about how it might be integrated into a whole class situation. It seems that the construction of a maze could be a highly creative activity but that it would be very time consuming for both teachers and students. Potentially this unit also could be placed in the revelatory and/or conjectural category.

7.4.10 Life Doesn't Run Smoothly

This unit is similar in style to *Jeans* and *Human Mosaics*, with the video being used as a stimulus for class discussion and no interactivity required. In this case the contexts are difficult social situations which require the application of some mathematical thinking. It is not clear whether the style of use being suggested applies to small groups or whole classes. However the designers appear to suggest using the video to stimulate full class discussion followed by work in small groups.

7.4.11 Short Tasks

The most obvious question to ask about this unit is "Why use the computer?" The unit consists of a collection of still images with written suggestions for mathematical starting points which could easily be presented in a printed format. There is no interactivity with the system and no provision for feedback.

7.4.12 Mechanisms and Linkages

This unit does exploit some of the unique features offered by the link software, there seems to be potential for exploring aspects of movement of the linkages. However the software is entirely open-ended and no support is provided by the computer. Such support might now be expected by many users. It seems that considerable structure would be required in order to integrate the use of this unit into a classroom situation. However a wide range of associated activities are supplied in the support materials. Potentially this unit also could be placed in the revelatory category.

7.4.13 Picture Gallery

Used in conjunction with the *Toolbox* software this unit also exploits some of the unique features of the link between computer and video system. Many associated activities are suggested in the support materials, some of which seek to exploit these features and others which might easily be carried out simply using printed materials. Once again considerable planning would be required on the part of the teacher in order to structure and integrate the use of this unit into a classroom situation. This is another unit which potentially could be placed in the revelatory category.

7.4.14 Challenge

This unit involves a curious mixture of approaches being, on the surface, similar in approach to traditional drill and practice software for basic arithmetical skills. However once the type of question, level of difficulty and time interval have been selected there is no opportunity for the user to interact with the system. An initial impression is that such an approach could prove to be very frustrating to a user who was getting left behind by the system and with no ability to slow it down. Additionally such a program could easily be devised to run on a standard computer system since the use of video is not a necessary element .

7.4.15 On the Move

Like *Mechanisms* and *Picture Gallery* the aim of this unit is to use the *Toolbox* software to exploit some of the unique features of the system. In this case use is made of moving video with the aim of investigating aspects of the motion. As with many of the other units there is a wide range of

Mechanisms and *Picture Gallery*, there would be a need for considerable planning and structure in order to integrate the use of this unit into a classroom situation. Cutler (1993) also notes that this section "above all others" would benefit from a guide to outcomes which might be sensible. Potentially this unit also could be placed in the revelatory category.

7.4.16 Toolbox software

The *Toolbox* software is of a standard design, allowing relatively quick and easy access to the various functions of marking points, drawing lines and measuring distances and angles. An aspect of the software which is not immediately apparent however is that it does not result in very accurate working. For example, in marking the three points on screen which maps out the angle between, say, the spokes of a wheel, there is much scope for error given the relatively approximate placing of the marker blobs. A similar problem is experienced in measuring the distance of a line which is given in *smidgins*; this is roughly the same width as a screen pixel. It is likely that this aspect could present difficulties for some students when using this software.

7.4.17 Summary of initial findings

In summary, much of the video on the discs is used as stimulus material with little or no level of interactivity. The designers do acknowledge, quite prominently in the support material, that the units vary in the amount and style of "multimedia activity" provided, but that all are designed with "classroom interactivity very much in mind". However it is the case that much of the package does not begin to fit into the categories for classifying educational software. In addition very few of the units have any element of feedback built into their design. These findings are summarised in Table 4.

The use of the *Toolbox* software makes four of the units potentially interactive and appropriate for the revelatory software category if used in this way. One element of *Number Games* and three of *Who Stole the Decimal Point?* are interactive, with the element from the first unit and one from the second fitting the revelatory category. The second and third

Unit	Interactivity	Software Paradigm	Feedback
Number Games	Yes - 1 scenario No - 6 scenarios	Revelatory Stimulus video	Yes No
React!	No	Data generation	No
Perspectives:			
(i) Alcohol	No	Stimulus video	No
(ii) Running etc	Yes	Revelatory	Yes
(iii) Cube Towers	Yes	Revelatory	Yes
Decimal Pt.	Yes - 3 elements	Revelatory - 1	Yes
	No - 16 elements	Stimulus video	No
Ways of Calc'ing	No	Stimulus video	No
Human Mosaics	No	Stimulus video	No
Jeans	No	Stimulus video	No
Powers of Ten	Potentially - Yes	Stimulus video/ revelatory	No
Labyrinth	Yes	Potentially revelat- - ory/conjectural	Yes
Life Doesn't Run Smoothly	No	Stimulus video	No
Short Tasks	No	Stimulus video	No
Mechanisms	Potentially - Yes	Stimulus video/	No
		revelatory	
Picture Gallery	Potentially - Yes	Stimulus video/	No
		revelatory	
Challenge	No	?	Yes
On the Move	Potentially - Yes	Stimulus video/	No
		revelatory	

Cycle 3 evaluation: Summary of initial findings

Table 4

sections of the Perspectives unit are in fact the only two examples where there is interactivity, the software category is revelatory and there is some feedback built in for the user. These are the sections *Running, Jumping and Flying* and *Cube Towers*.

evaluation of the package relates to modes of use and teaching and learning styles. The mode of use of much of the material is unclear. There is much reference throughout the support materials to both whole class and small group work.

Some of the issues relating to whole class use relate to:

- the inappropriate screen size for whole class use
- the possible usurping of a key function of the teacher's role in introducing activities
- whether this mode of use represents the most effective use of the computer system itself

Some of the issues relating to small group work use relate to:

- the need for advance planning and preparation by the teacher
- the need for some structure in order to integrate the activities into a whole class context
- the balance of time between computer-based activities and those away from the system
- the balance of time at the system between the groups

7.5.0 REFLECTIONS ON THE ORIGINAL PROJECT SPECIFICATION

The original project specification (NCC, 1989) highlighted aims related to the following areas:

- diagnostic assessment.
- conceptual understanding and skills in number
- a positive attitude to work with number
- progress through the levels
- independent investigation and work in small groups
- the encouragement of the natural curiosity of pupils
- the use of number in familiar everyday situations
- mathematics as a tool and means of communication
- the provision of support for less experienced teachers
- reflecting good practice in mathematics

- promoting the productive use of other resources
- appropriate level of mathematical challenge

In relation to the development of a *positive attitude* to work with number, it is clear that the package offers much potential. Opportunities for *independent investigation* and *work in small groups* are numerous, although at the same time raise issues of planning, preparation and classroom management for the teacher. There are also opportunities for the encouragement of the *natural curiosity of pupils*, for the use of number in *familiar everyday situations* and also for the use of mathematics as *a tool and means of communication*. There is a wide range of material which reflects *good practice* in mathematics education and which would undoubtedly *add value* to the work in the mathematics classroom. The extensive package of support materials undoubtedly *promotes the productive use a wide range of other resources.*

A missing element with the package as a whole is in relation to *diagnostic assessment*. Feedback in any form is a very limited feature of the package. Given the very great potential of the system for interactivity and feedback, this does seem to be a major deficiency of the package. There are major issues surrounding the balance between the level of *independent investigation* and *work in small groups*, and also between small group and whole class work. With regard to the provision of support for *less experienced teachers*, the level of organisational complexity of the package in itself would seem to be a very significant barrier to less experienced or less confident teachers. Combined with the complexity of classroom management issues surrounding the use of the package, it is very doubtful whether this aim has been achieved by the developers. In relation to the *level of mathematical challenge*, this is a very variable factor in the package. The publicity material associated with the package emphasises that the materials are particularly aimed at students who find mathematics difficult or uninteresting. There is no doubt that there is much in the package to engender interest but it is very doubtful whether the package meets the needs of the less able students. In terms of whether the materials and also to *progress through the levels*, it is not possible to judge from such an initial evaluation. Such judgements could only be made from a longitudinal study of classroom use.

7.6.0 ASSOCIATED LITERATURE

Cutler (1993) summarises with the view that the package contains "a wealth of good mathematical ideas" but that although many students would be highly motivated by using the discs, he has doubts about the cost effectiveness of the system in its initial form. He also raises questions about the length of time which many of the activities take, and which he observes "are really only suitable for small groups".

Barker (1992), in a critical review, highlights the "sheer weight and complexity" of the material as a major problem and one which he predicts will prove to be self-defeating. Questions are raised about the mode of use, noting that it is far from clear how the material will be used in the classroom and asking if it will be used by the teacher, a pupil or a small group. He offers the view that the "issues have not been thought through at all", alluding to the lack of clarity about how the materials are intended to be used in the classroom. He does conclude on a more positive note with the observation that the CD ROM based versions will have more chance of success because "CD ROM drives will be endemic in schools".

Hughes (1994) reports on the initial evaluation study into the use of interactive video and associated technology conducted on behalf of the National Council for Educational Technology. She notes "unsurprisingly", given what is already known about computers in education, that:

- the use of IV in the classroom must be carefully implemented
- teachers need time to familiarise themselves with the system and the discs
- activities must be structured and should mix on-line and off-line tasks

She observes further that all the evidence "reassuringly" reiterates what we already know about the use of computers in education. However she does forms of IT, which is "high quality moving images which engage students".

The danger of unproductive browsing is highlighted by Hughes, who notes that when students work with IV they want to press buttons and make things happen. There also is a reluctance to sit back and think about what they are doing and what they are learning. The advice from the NCET evaluation is that "reflective moments" should be incorporated into IV activities. A similar problem is highlighted by Goldstein (1990) when writing about the use of computer adventure games. He observes that: "In adventure games children are not usually interested in the mathematical problems themselves - only the solutions".

Sowerby (1992) reports on the classroom use of the *Number Games* unit and outlines an approach based upon teacher control of the system as an introduction to the whole class. He notes that the system was "certainly useful for the student who arrived late" and that it was also valuable for those who wanted a second chance to see the problem being set. A particular feature which attracts comment is the level of discussion generated. Other features which are highlighted relate to how "real problems" are presented to the students, the power of the visual medium, the positive reaction from the students and the perceived relevance of the problems set in this way.

7.7.0 FEEDBACK FROM TEACHER USE

The first comment from the Head of Department related to the organisational complexity of the package:

> *Well initially I think we were slightly overwhelmed by the amount of material on the disc ... there seemed to be so much on the disc initially ... that was a bit of a problem selecting what to use.*

Who Stole the Decimal Point proved to be the first unit that was selected, not only reflecting the interesting nature of the unit itself but also the relative ease of use, without the need for very much advance planning:

> *We, I suppose like most other schools, homed in on Decimal Point because that seemed to be the most interesting and so we spent*

quite a bit of time initially just familiarising ourselves. Also actually we just did run it with classes, just let it run initially, just to see their reactions and to give us a chance to use it.

There was early uncertainty about the teacher's role but the opinion was formed, at an early stage, about the need to structure the use of the package into the wider classroom context:

> *Initially we weren't sure how to use it, whether we should direct it or what ... We used it with quite a wide range of abilities and the kids responded very well to it. What we realised fairly early on was that you have got to structure it. It is a very nice resource with a lot of potential but you really have got to get to know it to get the most out of it. You have really got to target it, structure it and build it ... You had to really think about how you had to use it ... You have really got to be selective ...*

The most significant barrier to the use of the materials related to the need to integrate this with the ongoing scheme of work:

> *I think the biggest problem is how to link it in with the scheme of work that you have got ... from a Head of Department's point of view ... I would not just want to see it used willy nilly, because I think if you do that then once staff have had a go with it, it is a novelty item, and then it tends to get left on the sidelines ... and gather dust if you are not careful ... One of the problems is to build in, to sort out what's there, and to pick out what you are going to use and to build it into some scheme.*

Whole class work had been the predominant mode of use, in the initial stages, up to that point in time. In some cases whole classes worked on a common problem, in others the class was split up into smaller groups working on different problems. The advantages of small group work were clearly recognised, as were the disadvantages with large groups of lower levels of involvement and also the limitations due to small screen size. The role of the teacher was emphasised in the small group situation, with this way of working being seen to be the preferred mode in the longer term:

> *In most cases I think it has been whole classes. Certainly initially staff have used it in different ways and some staff homed in on particular problems, maybe two or three problems and have done it as a whole group exercise and others have started off initially like that and then they have left small groups to work on different*

groups the kids get a lot out of it. There is the danger with a big group that some of them don't get involved. In small groups you can more easily get them all involved but you have got a bigger balancing act ... You have got to be on the ball yourself to manage it and to provide a stimulus and ask a lot of questions. It comes down to time as well, whereas if you are doing it as a whole class exercise it is obviously easier to focus on particular problems. I suspect as we become more familiar with it we would move to mainly a method where we are working in small groups. It really, in the end, doesn't suit the whole class, the screen is too small, only one person can work the mouse.

However there was seen to be a limiting factor in relation to group size, based on practical considerations:

> *If one or two are only on it then it takes a lot of time for the whole class to get round to having a go ...*

The system was not seen to be particularly effective in terms of promoting independent learning, with the role of the teacher once more being emphasised:

> *There are bits of it where it would be quite difficult to do it on their own. You need a lot of teacher input. It goes back to one of its strengths - it can be used in a variety of ways - it is suitable in parts for independent learning but I personally wouldn't like to see kids just left to their own devices, teachers play a very important part in drawing things together.*

This role of the teacher was highlighted further in relation to working with low achievers:

> *They tend not to be very good at strategies and if you lead them in the right direction they do get a lot out of it. Once you nudge them in the right direction they get a lot out of it.*

There was little doubt about the motivating aspect of the package, although the novelty factor was acknowledged. Particular features which were highlighted in this regard related to the use of peers on the video, the interactivity and the establishment of real world contexts:

> *Well it is certainly a highly motivating piece of equipment but*

that they are using kids of their own age, sort of peers. It is written at the right level. The interactivity is motivating. There is quite a lot of material on there that is not interactive and they still find that interesting, where it involves their peers. They are presented with a problem which involves their peers acting it out as a work situation and you know they are not maybe, after that, interacting with the system, they still find it motivating. I suppose ... it's because it is in a real life situation ... in the real world.

In terms of the level of mathematical challenge, this was seen to be very variable, which presented both advantages and also some difficulties:

> *In terms of maths problems, one is knowing which level - some problems are so open ended that you can use them with anybody. There are other problems where you have really got to think carefully about which group you are going to use them with ... There is quite a wide variation ... that is one of the attractions of it - the fact that there is such a wide variation, that you can pick and choose ... in the end that is why it is suitable for such a wide range of kids.*

Support for aspects of basic numeracy was not seen to be the strength of the package, which was seen to be more related to the *process* aims of using and applying mathematics:

> *I think it's quite patchy to be honest. I think it's very good for Ma1 - "Using and Applying" - choosing the right sort of maths, ways of working, communicating and responding. In terms of content for Ma2 (Number) I am sure there is a lot there but I think it is patchy and quite difficult to pluck it out if you were wanting to match it in that sort of way.*

On the question of interactivity, it was recognised that many of the activities could have been carried out using video. However the system did enable easier access to the material:

> *Well the interactivity is on two levels. I think in a sense some of them could be done just as easily on video but you've got more control or the control is easier I think on the system compared to video - replay, stop ... There's that sort of interactivity that maybe that's just control. But then there's the genuine interactivity where you trying out your solutions as in real time as it were on*

the system and that's affecting the next stage of your progress.

In relation to the use of the video element, it was recognised that this had not been fully exploited in the units used up to that time but pointers to possible future development, which followed some preliminary informal exchange of views, were outlined:

> *Well from the stuff that we've used ... I'm not sure that its been used to its full extent and I can see, on some material, the video element would be more important because it gives you access to real life situations that you couldn't do in any other way. I'm thinking of the matching graphs, the Running, Jumping and Flying - you've got the video of the plane landing and pole vaulting ... that seems to me that sort of exercise is really using the potential in a good way. You've got real life situations, you've got the control to match graphs to a situation. You really couldn't do that in any other way.*

Final concluding thoughts led to a futher emphasis upon aspects of planning, preparation, management and overall structure. Some criticism was made of the lack of practical support that was offered by the package:

> *I think there needs to be an awful lot of work, more work done on support materials. I think they are quite weak ... The worksheets are not quite useless but are not particularly helpful either. Although it's obvious that some attempt has been made to help teachers ... in terms of actual use in the classroom, if schools were given this system they need to put quite a bit of work into the overall management and planning of use in terms of ... preparation, planning and worksheets ... in terms of what should follow ... I think our major priority is to develop some way of working with it which has some logical progression ... You've got to plan it ... How you are going to use it, what you're going to use. That's quite a major issue really, it takes some sorting out.*

Interviews with other staff in the department served to offer further evidence to support some of the issues raised by the Head of Department but offered no particular new insights or issues to be considered.

Two one-day visits were arranged to the trial school and on each occasion four lessons were observed which involved the use of the package. The first day involved a more detached style of classroom observation than the second, in which responsibility was taken, by the researcher, for the group working at the system.

The first lesson to be observed on the first day involved a Year 8 Set 2 group of 28 students. These were divided into three groups of between 8-10 students, with one group working on the system and the others on related activities prepared by the teacher. The first task involved the group in trying to solve the problem *Dress* from *Who Stole the Decimal Point*. The problem is to guess how much the dress cost when new, given feedback from the system on whether the last guess was too high or too low. The key to solving the puzzle is the realisation that the dummy always tells lies. The group was very slow to develop a strategy despite the fact that they seemed to expect the dummy to lie. However after considerable time and effort they did reach a solution. The next problem to be tackled was *Boat,* in which a group of students respond by standing up or sitting down in response to numbers entered into the system. In fact the pattern of their movement is based upon binary numbers. The group had the idea that digits might match individual students but when this was eventually seen to fail, they very nearly gave up trying to solve the problem. Only the intervention of the teacher prevented this and directed them towards a solution.

Then followed a period during which there was a lot of flitting around the software to find problems which could be tackled and several were simply left unconsidered. There seemed to be an expectation that all the problems could be tackled there and then on the system, whereas in fact many needed to be taken away to be worked on before returning to the system with solutions. The teacher needed to intervene again in order to direct the students to this course of action. There was some frustration on the part of the pupils that this was necessary.

lesson was introduced through a teacher-led activity involving guessing a number. This task was then carried out in pairs and followed up by a class discussion on appropriate strategies. The whole class was then introduced to the problem *Dress* and, together with some open and some more directed questioning by the teacher, a solution was reached. *Boat* was the next problem to be considered and initially there was a great deal of wild guess work. Once again, teacher intervention was needed in order to lead the group towards a solution. There was considerable difficulty in maintaining the interest and involvement of all the group during this activity. The next problem was *Bells* which involved trying to work out the rules governing the switching of them on and off. Once again the initial reaction was wild guessing which was only given direction by the intervention of the teacher. At the end of this session the teacher indicated a lack of satisfaction with the lesson. In fact a follow-up activity on binary numbers had been planned but was abandoned on seeing the difficulty the students experienced with *Boat*.

The next lesson focused on graphical interpretation with a Year 10 Set 2 group. There was a very clear structure to this lesson, which had been planned by the teacher. The first activity was a whole group discussion involving the interpretation of graphical information from a prepared worksheet. The second activity made use of the software program *Eureka* which involves the mapping out of the water level in a bath given options such as turning the taps on and off, putting the plug in and out and letting the "man" in and out. There was some well directed questioning in order to predict "What will happen if?", together with a good level of student response. The next activity involved a demonstration and discussion of the one hundred metres race from the *Running, Jumping and Flying* section of the *Perspectives* unit. Small groups then took it in turns to look at small sections of this aspect of the disc. The students were encouraged to describe what was happening in the motion, to choose an appropriate graph and then to write about this in their books. The full potential of the software was not utilised however and there was very little opportunity for exploration, discovery or discussion, given the limitations of the task and of

The final lesson involved a Year 7 group using *Who Stole the Decimal Point*. An early observation from one student was "Sir, this is like *Crystal Maze*!". This comment seemed to encapsulate the source of the undoubted motivation generated by this unit (*Crystal Maze* being a popular adult TV adventure game). The whole class was introduced to the system and the problem *Dress*. The group was very enthusiastic and there was a great variety of responses. Eventually the class was guided towards the discovery that the dummy was lying and then quickly reached a solution. Two further problems were then introduced which were supported by handouts prepared by the teacher. A free choice was given of which problem to work on first. There was a high level of motivation with students keen to try out their solutions on the system.

The second day involved more direct involvement with the groups working in the system, in contrast to simply observing the action. This day involved working with groups on *Decimal Point* and offered few new insights but did reinforce the finding related to the importance of the teacher's role. There was a need for a considerable level of teacher intervention in order to ensure continuing progress on many occasions. Some of the tasks were unclear to the students and problems were encountered due to the variable level of difficulty of the problems. A group of nine Year 9 students proved to be too large for a high quality of interaction to take place. However the unit did motivate interest, but considerable direction was required in order to maintain progress. On many occasions the groups would have given up on a problem without the intervention of a teacher.

In summary, findings from the periods of classroom observation particularly served to reinforce the importance of the role of the teacher in terms of guidance, support, intervention and, at times, direction. The group which was given the most "free rein" started to flit around the system looking for easy options, as they found many of the problems difficult to engage with. There was also considerable evidence that they were starting to get frustrated and were very much in need of some teacher direction, only group observed which was not using *Decimal Point*. This lesson was the most interesting in terms of the degree of original thinking which had gone in to it. There was evidence of a real attempt to structure the activities and integrate the use of the system into an ongoing scheme of work in a creative way.

7.9.0 OVERALL SUMMARY

The interviews with teachers and the classroom observation served to confirm a number of the findings based on the initial findings and the consideration of the associated literature.

7.9.1 Organisational complexity

The organisational complexity of the package did present a real, but not insurmountable, problem in the early stages.

7.9.2 *Who Stole the Decimal Point?*

Decimal Point did prove to be the most accessible unit but there was considerable evidence of the danger highlighted by Goldstein (1990) of a preoccupation with a "solution" to the game, rather than the mathematical problems themselves. Only vigilant observation and teacher intervention ensured continuing progress and avoided frustration setting in on several occasions.

7.9.3 Mode of use

Uncertainty was apparent with regard to the mode of use of the materials. There appeared to be a not unreasonable expectation that the designers would have addressed this issue, but also an early realisation of the need to structure the use of the materials into the wider classroom context. There was also the recognition of the associated need to integrate its use with an ongoing scheme of work.

7.9.4 Whole class use

The predominant mode of use had clearly been whole class use despite a clear recognition of the limitations due to screen size and level of pupil from the classroom observation, even with groups of between eight and ten.

7.9.5 Motivation

The motivating aspects of the package which were particularly noted in the teacher interviews related to real world contexts and also to the use of peers as presenters of the activities. This latter aspect is particularly emphasised by the members of the development team: Phillips, Pead and Gillespie (1995, to appear), who offer some observations on their own evaluation of the package.

7.9.6 Level of challenge

The level of challenge in the materials is confirmed as being quite variable. From the interviews with staff, this was seen to offer an advantage, in terms of applicability to a wider range of pupils, but did present particular problems for some students when encountering a problem which was really beyond their capability during the classroom observation. The need for guidance and support from the teacher was apparent in such cases.

7.9.7 Basic numeracy support

The level of support for basic number work and low achievers in this context was not seen to be a strength of the package by the teachers. Evidence from classroom observation supported this view and confirmed that *Decimal Point,* in particular, was concerned with problem solving skills and strategies rather than basic numeracy.

7.9.8 Interactivity

The issue of differing levels of interactivity had clearly been identified by the staff, but this was not an immediate issue given their stage of development in using the package as a whole and the lack of any necessity to consider issues of cost effectiveness.

7.9.9 Role of the teacher

The major issue to emerge from the interviews with staff and which was reinforced during classroom observation relates to the role of the teacher, the point of view of planning and structuring the activities into the context of the whole classroom and integrating these with an ongoing scheme of work. Secondly is the importance of the role in terms of guiding, supporting, intervening and, also at times, providing direction.

7.9.10 *Running, Jumping and Flying*

The unit to emerge with the richest potential for further development is *Running, Jumping and Flying*, given the fact that this unit was one of only two units in the package where there is interactivity, the software category is revelatory and there is some feedback built in for the user. The full power of the computer and moving video facilities are utilised in this real world simulation, in a way which could not be achieved by any other medium. Discussions had identified this as an area of interest on the part of the staff and some limited experimentation had already been undertaken in the classroom by one member of staff. An added advantage was the easy identification of an area of the mathematics curriculum for which the use of this unit would be relevant, although of little direct relevance to number.

For these reasons, it was decided to concentrate the next development stage of the study on exploring the potential of this aspect of the package. By this means this study would come to represent an investigation of the full technological potential of multimedia in the mathematics classroom whilst, at the same time, focusing attention on the potential of collaborative learning in this context.

8.0.0 CYCLE 3: CLASSROOM TRIALS AT SCHOOL C

8.1.0 INTRODUCTION

School C is a mixed 11-16 comprehensive school in Barnsley serving a community on the outskirts of the town. The school appears to be a popular one in the area with good standards of achievement. Following the initial school visits and discussions with staff, it was agreed that the unit *Running, Jumping and Flying* should be the focus of the next developmental stage of the project, for the reasons outlined at the end of the previous chapter. In this chapter the planning process will be outlined, the resulting materials and activities described and an account will be given of the classroom trials. The initial data analysis is reported upon but, in view of the scale of the tape transcript data, a single chapter is devoted to this, which forms the core of the following chapter.

8.2.0 FORWARD PLANNING

8.2.1 The Forward Plan

The planning process began by identifying a group to work with and a relevant unit of work into which the use of the package could be integrated. Following discussions a Year 9 Set 1 group of 30 pupils was identified as being an appropriate choice. This particular group was chosen because the class teacher was the Head of Department, who was instrumental in leading developments relating to multimedia in the school, and also because the use would fit in with the planned scheme of work in the Spring Term. The scheme of work was loosely based on the SMP Yellow series of books and the group was due to do a unit of work on graphical interpretation based upon Chapter 1 of Book Y2 at that time. It was agreed that the planning and preparation would be undertaken in the first instance by myself, and that the plan and activities would be finalised following discussions prior to the classroom trials. It was also agreed that we would work jointly with the group during the trialling.

The first stage of this process was to draw up a forward plan which is presented in Figure 5:

FORWARD PLAN

Lesson 1

START to FINISH dice game (Worksheets 1-3) - whole class activity.
Travel graphs (Worksheet 4)
Review slope of line/steepness of line.
Introduce the term *Variable.*
Discuss making the graphs more realistic i.e. changes not instantaneous.
Extension and/or homework: *Y2/p1/A1*
Y2/p2/Read and try A2 and A3

Lesson 2

Review of Lesson 1 (and extension/homework).
Emphasise graphs showing *relationships* between *variables.*
Discuss *linear* and *non-linear* relationships with whole class.
Introduce the IV disc to whole class - outline the context/activity
- Factsheet on 1988 Seoul Olympics

Run full screen of Women's 100m for whole class

What does the graph of distance against time look like?
Discussion/suggestions/sketches on board.
Use TEST facility to overlay graph onto full screen video.
Replay using PAUSE to examine particular features of the graph i.e.
time taken to get started, how long to get up to full speed?
What other graphs could we think about?
speed against time, other - acceleration?
Leave class to think about and sketch what the graph of speed against time might look like (opportunity to test ideas on the system in due course).
Explain arrangements for small groups - composition/approx timing.

Whole class to complete work from Lesson 1/work on *Y2/Section C/p6-7*
Small group(s) working at IV system.

Lesson 3

Review of progress with Y2.
Discuss *proportionality/non-proportionality* with whole class.
Whole class to continue with work from *Y2/Section C* and *to start Y2/Section D.*
Small groups working at IV system plus follow-up activity.

Lesson 4

Review of progress with Y2.
Whole class to continue with work from *Y2/Sections C/D (also Section B - Discontinuous graphs)*
Small groups working at IV system plus follow-up activity.

Lesson 5/(6)

Review of progress with Y2.
Whole class to continue with work from *Y2/Chpt 1 and Y2/Review 1/p50*
Small groups working at IV system plus follow-up activity.
Overall review of all activities/display of posters.

Figure 5

The first stage in drawing up the forward plan involved an analysis of the content of the planned unit of work in Book Y2. The unit is concerned with relationships and begins with a consideration of graphs which illustrate examples of these. Variables are considered in the next section, leading on to discontinuous graphs, linear and non-linear relationships and proportionality (see Appendix 1 (i)). The overall approach of this unit was thought to be rather fragmented and the order in which the aspects were considered not necessarily the most appropriate. In addition the unit lacked any suggestions for activity based work, relying instead on the more traditional formula of problems and exercises. Therefore it was decided to adopt a more holistic approach to the unit as a whole, basing the forward plan upon graphical interpretation and integrating activities both on and off the system with aspects of work from Y2. It was thought that the work from Y2 could prove to be a useful backdrop in order to provide sufficient resources for a two week module of work. This would ensure that there was always some element on which students could continue to make progress, even if they were waiting for a turn on the system and also provide opportunities for homework.

The dice game *Start to Finish* was planned as a whole group activity which was considered to be appropriate in terms of setting the scene, promoting discussion and generally stimulating interest and involvement (see Appendix 1 (i)). The main mathematical aim of this activity was to develop an understanding of distance-time graphs and to be able to interpret the meaning of steeply and less steeply sloping lines, flat sections etc. in terms of the motion. Worksheets 3 and 4 (see Appendix 1 (i)) aimed to develop this further in the context of whole class activity. Sections from SMP Book Y2 were identified for extension activities and/or homework if required.

The second lesson was envisaged as building on the first, with an initial review and whole class discussion at the start. The next stage of the lesson was planned as a whole class introduction to *Running, Jumping and Flying* with the aim of setting the context and giving the students a sense of what element was the women's 100m race in the Seoul Olympics. The intention was to play the sequence in full screen motion and to then discuss what the graph of distance against time might look like. Following the discussion, the facility for testing the choice would be used to illustrate how the graph could be overlayed onto the motion, once the correct choice had been made. Using some of the other features of the software, the intention was to examine some of the particular aspects of the motion, such as the time taken to get underway, as suggested in the support materials accompanying the package. Other aspects which were identified for possible discussion included speed, and also possibly acceleration, against time.

At this stage some groups would begin working on the activities at the system. An ideal group size of three had been agreed with the class teacher, based upon the previous experience of Cycles 1 and 2, with the aim of creating the conditions for effective interaction. This resulted in ten groups in total. Each group would be allocated an initial period of thirty minutes for intensive work at the system. The practical limitations were eased considerably by the recent addition of a CD ROM drive by the school which enabled the class to utilise two systems, given that there was also access to the CD disc version of *Running, Jumping and Flying*. This provision would enable four groups to carry out the multimedia based activities in a one hour lesson and for each group to have a turn over the period of a single week. The class was timetabled for two lessons of approximately one hour and one of half an hour per week.

The first planning day was spent giving consideration to the whole class and very little to the multimedia based activities, as the following diary entry shows:

> *I have spent the entire day considering the whole classroom i.e. what everyone in the classroom might be doing and also the progression of activities. I have created a framework into which the multimedia based activities will fit. There is a mixture of activities for the whole class, text based material from Y2 (hoping that the classroom climate will encourage discussion between pairs), activities for pairs and multimedia based activities for*

the ongoing scheme of things that has not been addressed by the authors of World of Number.

This process had been very much concerned with the creation of a "framework" or a structure for the whole classroom and attention was then turned to the multimedia based activities. Although considerable work had been put into the provision of supporting activities by the developers, these did not seem to be within any overall structure and were consequently not as supportive as might otherwise have been the case.

8.2.3 Multimedia Based Activities

In fact some of the support materials were utilised in devising the system based activities. In particular the *Screen Control* Help Cards (see Appendix 1(i)) and *Factsheet* on the Seoul Olympics were used. Versions of the *Screen Control* Help Cards were also printed off from the CD ROM disc. The overall guide to screen control is illustrated in Figure 6.

The guide to the sequence selection is illustrated in Figure 7 on the following page. Each sequence has two or three graph options associated with it. For example, in the sequence shown in Figure 6 opposite the chosen axes in the bottom left hand window are height and time. Other choices might be distance against time and speed against time. This would give three graphs to choose from in the bottom right hand window. The combined choice is illustrated in the top right hand window.

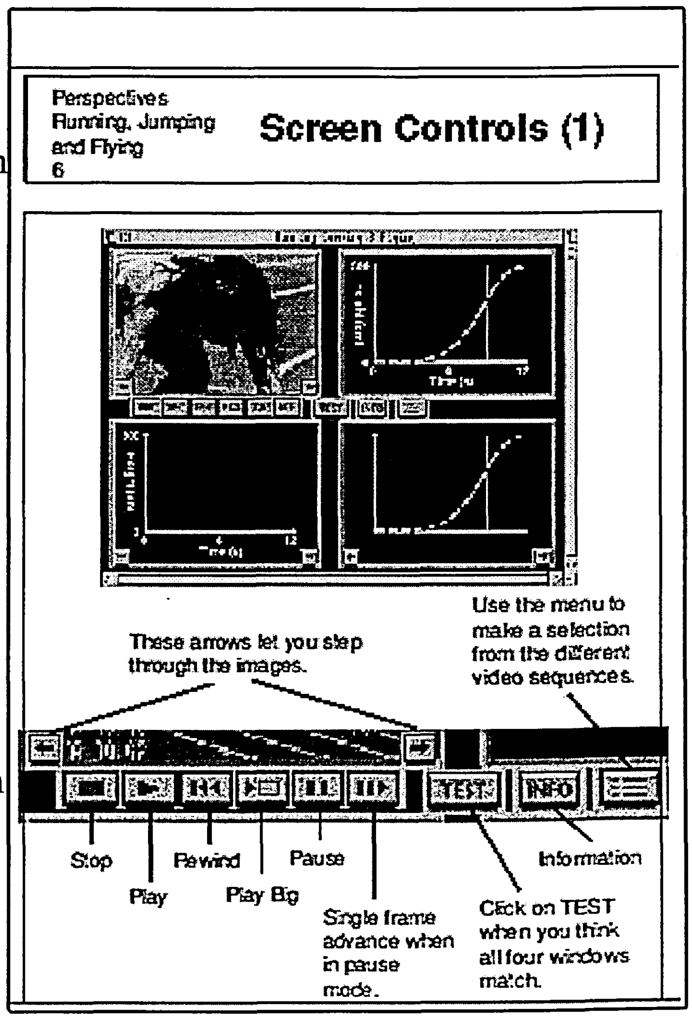
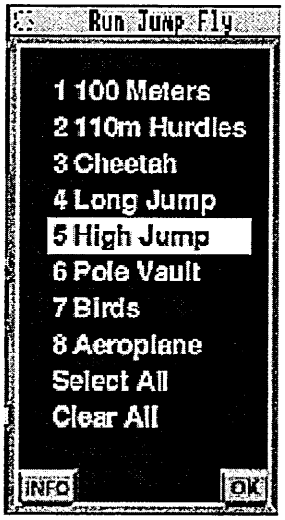


Figure 6

Perspectives
Running, Jumping and Flying
7

Screen Controls (2)

This is the Running, Jumping and Flying menu.



To choose an event, click on it. It is easiest to start by choosing just one example.

To clear all selections click on the 'Clear All'.

Figure 7

GROUP ACTIVITY Card (1)   Using the Multimedia System

For this Activity you will be working as a group of 3.
You will need a clipboard, paper and a pencil.
Take it in turns to control the keyboard.

1. Decide on which video sequence you wish to view first and select it.
See HELP Card *Screen Controls (2)*.

2. Watch the video sequence and think about what the graph of *distance* against *time* looks like.
Sketch your graph and compare it with those of the rest of your group.

3. Select the *distance* against *time* axes in the lower left window - see HELP Card *Screen Controls (1)*.

4. Select your choice of graph from the lower right window - take it in turns to explain your choice and also your reasons for **not** choosing others.
Then use TEST to see if you are correct.

5. Now select another set of axes for the same video sequence and repeat the process.
If this is the only remaining sequence take it in turns to explain why you think the graph is the shape it is.
Then use TEST to run the video sequence, using PAUSE to examine the motion more closely if necessary. Make a sketch of the graph.

6. Now let someone else take control of the keyboard and return to the main menu via MENU.
Clear your previous selection using CLEAR, choose another video sequence and repeat the whole process.

Figure 8

By selecting up to a maximum of four sequences at any one time the user could in the end have to consider the matching of up to twelve different graphs and sets of axes. This course of action is suggested in the support materials, but with the rider that for "younger students it is recommended that they only select one sequence at a time." The latter strategy was that adopted, as the view was formed that this would provide sufficient challenge for a Year 9 Set 1 group. In fact, the complexity of the former course of action, in all likelihood, would be quite bewildering even for older and more able students. The danger of wild guessing under such circumstances, and the need to work to prevent this, was also at the forefront of the thinking at this stage.

The resulting group activity is outlined in Figure 8. The main aims of this activity were to promote discussion and require time for reflection which evaluation, as reported by Hughes (1994), of the need for "reflective moments". The activity was structured in such a way as to encourage the following process:

- select and view a video sequence
- think about the distance-time graph
- sketch the graph
- compare graphs
- choose a graph which fits your ideas
- explain to each other why a particular graph does or does not fit
- test out choice on the system
- repeat the process with a different choice of axes

This process can be summarised as a **cycle of observation, reflection, recording, discussion and feedback**, as illustrated in Figure 9.

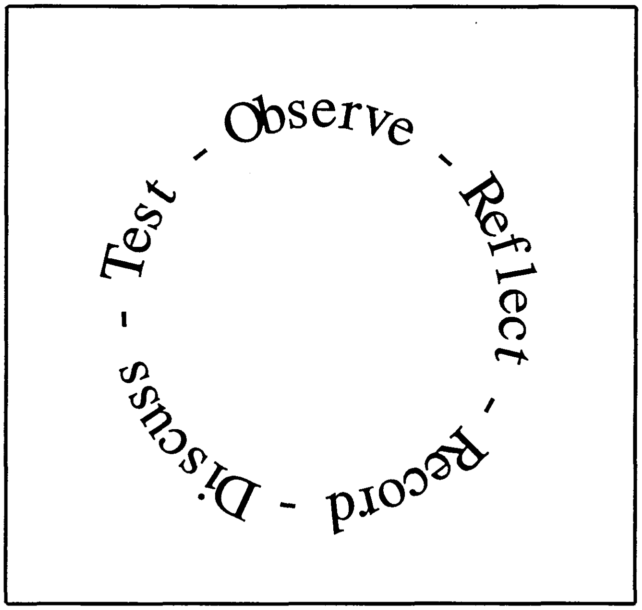


Figure 9

Once the group had worked through a sequence following this process, they were asked to pass over control of the system to another member of the group and to repeat the cycle with another sequence. A follow-up group activity was designed around the task of a joint poster display to illustrate at least three of the video sequences and the associated graphs of relationships between various variables. This activity is outlined in Figure 10 on the following page.

GROUP ACTIVITY Card (2)   Away from the IV System

Choose at least 3 video sequences around which to create a poster display.

Use your sketches to draw graphs showing relationships between, for example:

height and time
distance and time
speed and time
etc

Write some notes by each of your graphs to explain what each one is showing.

Figure 10

On completion of this stage of the planning process, the following reflections were recorded:

> *Essentially I have addressed the issue of the whole classroom and how the system might be integrated into the ongoing scheme of work (this the authors of World of Number seem to have singularly failed to do). In addition I have devised group activities at the system and also away from the system. The purpose of the activities is to try to ensure meaningful interaction between the students and also between them and the computer. It would be very easy to just flick through the sequences guessing the "right answers"! (We shall see!)*

An overall impression that had developed by this stage of the project was that the design of the materials seemed to be most appropriate for the needs of an individual user. Although there were many references to small group and whole class work in the support materials, there was very little practical help in structuring this. The final reflection on this practical planning stage pointed back towards a reconsideration of a theoretical perspective which would accommodate a collaborative approach to teaching and learning:

> *Does the failure, by the authors, to address the whole class (and the group activity) reflect the trap/failing of a predominantly individualistic constructivist perspective? Further consideration of the socio-cultural theory of Vygotsky might be appropriate at this stage.*

A meeting was arranged with the Head of Department in the week prior to the start of the classroom trials. These were planned to take place in the second half of the Spring Term over a two week period. All the group's mathematics lessons during that time were devoted to the project. In both weeks the group had two one hour lessons followed by one lesson of half an hour. The proposed forward plan was welcomed and agreed together with the associated activities. Organisational issues relating to group composition, patterns of rotation, seating plans, equipment etc were discussed and agreed. In relation to group composition, this was organised by the class teacher and was loosely based upon friendship groups. Data collection methods were discussed and agreed. It was also agreed that the pre-test could be conducted later that same day, so as to enable a start to be made to the project at the beginning of the following week.

The first lesson was introduced by myself with a brief introduction about my background and the plan for the following two weeks. Advance notice was given about the use of the video camera, which had been agreed with the class teacher and previously discussed with the class. This involved the recording of the small groups working with one of the multimedia systems, in the main. The available time would allow for the recording of four groups of three working at the system for approximately thirty minutes each. Finally an outline of the particular lesson was given.

The rules of the dice game *Start to Finish* (see Appendix1(i)) were then outlined and a few throws of the dice recorded with the whole class. Following further discussion and clarification the worksheets and materials were distributed and the class started the activity, working in pairs. At this stage the class teacher and myself were able to circulate and talk to pairs of students working on the activity. The activity was well received and soon all the students were fully engaged with it. After ten to fifteen minutes most of the pairs had reached a point where one of them had reached the finish. At this stage there was an increased need for teacher intervention, mainly to smooth the transition to the follow-up activity on Worksheet 4 (see Appendix1(i)), and in some cases simply to give reassurance.

Most of the class had finished both worksheets within the planned time and were redirected to consider changing the rules of the game, which most of them had initially not tried. Those who completed this stage were directed to some of the extension work from the SMP text Y2. During the final quarter of the lesson the class was brought together and the results of the activity discussed with the whole group. The response seemed to be positive, with many offers of answers to questions, and the impression was formed that the task had been understood and enjoyed by all. This impression was confirmed by the evidence provided by the written work which was handed in at the end of the lesson. As homework was expected the students were all asked to complete questions 1 to 3 from section A of the SMP text for next lesson.

The second lesson was also introduced by myself with a review of the first lesson and also of the results of the homework exercise. A brief introduction was given to linear and non-linear relationships in order to enable those students who would not be working immediately on the multimedia system to proceed with work from the SMP text. The next stage of the lesson was the planned introduction to *Running, Jumping and Flying* for the whole class, on the multimedia system. The women's 100m race in the Seoul Olympics was played in full screen motion to the whole group and then the class was asked to think about what the graph of distance against time might look like. There were many offers of suggestions in response to questions and some students were invited to sketch their ideas on the board. Eventually the test facility was used to confirm the general consensus which had emerged. The facilities to pause and replay the motion were used to examine this in more detail. In particular the time taken to get started had not been anticipated by anyone, but on closer examination, the correct reason for the initial flat section of the graph was offered by several students. Following this introduction two groups were identified for starting to work on the systems, whilst the rest of the class continued to work from the SMP text. At this stage, I took responsibility for ensuring the progress of the groups at the systems whilst the class teacher focused on the rest of the class. In addition, two student teachers involved in the general supervision of and interaction with the students.

The groups were introduced to the systems and reminded of the structure of the task. During this preliminary phase, support was available to each group at the system from the class teacher and myself, whilst the student teachers generally supervised the rest of the class whilst they settled down to their tasks. In addition to supervising one of the groups working at the system, I also ensured that the video camera was set up and functioning. Hence the majority of my time was spent with the group being filmed.

The third lesson was the shortest lesson of the week and for that reason, there was a short briefing at the start of the lesson followed by a continuation of the plan from the first lesson. Two further groups were now engaged in using the system, with the rest of the class involved in work from the text book or in the planning of the follow-up group activity. At the end of this lesson the books were collected in for checking and marking by myself.

Between the third and fourth lesson three further groups had volunteered to come in at lunch and break times to complete the system based activity. There remained three groups to use the system for the first time during this lesson, two of which were filmed in the process. This resulted in a total of four group recordings of approximately thirty minutes each involving the use of both the Interactive Video and CD ROM systems. There were two groups of three boys and two groups of three girls. All the groups in the class were of single sex.

The marking of the books between the third and fourth lessons also highlighted a need for the clarification of some aspects of the text-based work for several students. The most efficient way of dealing with this was for a whole class review and discussion at the start of the fourth lesson, which the class teacher elected to do. At the same time, a group who had not had any difficulties worked with myself on the system based activity.

producing a poster. The groups were quickly organised and the activity soon underway as a result of the joint effort of myself and the class teacher. The students were generally enthusiastic about the task, with some groups electing to return to a system for a short time to review a particular graph and/or sequence. Much of this lesson was also recorded on video.

The final lesson was the second one of thirty minutes duration. During this lesson interviews were conducted with two of the groups which had been filmed using the system. These were semi-structured group interviews conducted by myself. Whilst this was underway the rest of the students were involved in completing their posters.

8.4.0 INITIAL OBSERVATIONS

The activities in general seemed to be well received by the students and also by the class teacher. In addition the student teachers became fully involved with all stages of the project and freely volunteered their time throughout.

The initial activity was judged to be successful as an introduction in view of the level of interest and involvement engendered and also by the level of mathematical understanding evident from class discussion and also from the assessment of students' written work.

The system-based activities seemed to generate a great deal of interest and enthusiasm. All the students appeared to be keen to be involved in these activities. There also appeared to be a rich level of interaction from these activities at the systems. A significant factor was the frequency with which a teacher became involved in the these interactions, sometimes in response to a request but on other occasions as a result of observing the interaction between the students themselves and/or between them and the system.

8.5.0 SUMMARY OF DATA COLLECTION TECHNIQUES

A pre-test was conducted before the start of the trialling process. Post-trial semi-structured interviews were carried out with two groups of students as already outlined and also with the class teacher. Post-trial questionnaires the relevant work had been completed and delayed post-test conducted several weeks later. The interviews were audio taped and subsequently transcribed, the questionnaires analysed and the tests marked.

The video recordings of the four groups working at the system were transcribed in detail together with supporting context notes in order to provide a basis for intensive qualitative analysis. The video recording of the fifth lesson when the whole class was involved in the poster activity was not transcribed, as it illuminated little about the nature of the interaction between individuals in the classroom. An ongoing diary together with lesson notes was kept throughout the period.

8.6.0 ANALYSIS OF DATA

The results of the initial data analysis are presented in this chapter and those based on the analysis of the video tape recording in the following chapter.

8.6.1 POST-TRIAL INTERVIEW WITH CLASS TEACHER

Feedback from the post-trial interview with Head of Department and class teacher confirmed the initial observations about the success of the activities in motivating the students, as the following comments indicate:

> *In general we think the system has got enormous potential ... It certainly motivated the kids - they were very surprised by the fact that they were seeing video images ... the fact that they could control it with a computer ... It really engaged their interest ... so it fitted in quite well with the approach we take with investigational work.*

The plan to integrate the activities with the ongoing scheme of work was clearly perceived of as a success:

> *I was interested in how you could integrate it more into the content of what we do. I thought that's probably where the real potential lay with it ... I think we found in working with that Year 9 group that it's got real benefits.*

In relation to small group work, it was felt that the group size of three had worked well, but there was also a wish to have been able to use the system practical limitations:

> *I felt ... that three interacted quite well and it is a good number to use ... I would quite like to use it with bigger groups as well, with whole class discussion, because there comes a point where you want to talk to the whole class or perhaps half the class to make sure they've got their understanding, with questions and answers, and it's nice to be able to have the system there but it's then a problem that you've got a small screen and that is quite limiting in the end. You've got kids ... who can't see what's going on.*

In response to being asked to consider some of the more difficult graph options, such as distance against height, the importance of teacher intervention was stressed:

> *Well I think without teacher intervention, I don't think they appreciated the difference - the subtle differences between the two, between vertical height and distance, and vertical and time, for example, and so it certainly needed some teacher intervention to draw that out but I think ... the subtle differences are quite difficult to appreciate, just on their own I don't think they would have thought about them. But once you started to question them they could get to grips with it - the fact that the distance one stopped at the end whilst the time one went on - they could see that (by running the video).*

8.6.2 POST-TRIAL INTERVIEW WITH STUDENTS

When asked to reflect upon what they had learned in using the system, Claire and Laura emphasised how it had helped them to make sense of the situation:

> *Working out what graphs would look like - it helped when we put the graph across the screen, when it was playing it - it showed what was happening.*

They indicated that they had not understood graphs at the start but were able to comment on how they made sense of some of the more difficult graphs by the end:

> *There were some graphs where you were asked to look at say height against distance. They were more difficult to work out*

a normal graph like we were used to drawing ... you had to look closely at the scale of the axis.

Neil, Jonathan and Philip highlighted aspects of the video element as their major reason for enjoying using the system:

> *Real graphics instead of just drawings of people.*

They emphasised how the use of the system had helped them to make sense of graphs, seemingly for the first time:

> *I hadn't done graphs before so that was entirely new. Well I knew about them but I didn't know that you could just get them onto paper by just looking at somebody running or something like that.*

They also emphasised the advantages of joint effort and of sharing ideas when working in small groups:

> *When you all work in groups you can all put a bit towards it and get more out of it ... more people on it. It's like you think of one idea and someone else thinks of it. So that helps.*

8.6.3 FEEDBACK FROM THE STUDENT QUESTIONNAIRE

There were twenty eight students present in the class, out of which only one girl had not enjoyed working on the topic. This seemed to be due to the fact that she did not get on with the other members of her group. Twelve indicated that they had enjoyed working in groups "very much" and a further eleven "quite a lot". Reasons given were:

Possibilities to discuss things	12
Exchanging ideas/sharing ideas	5
Helping each other	5

Four students linked one of these factors to "getting better results."

The responses to using the multimedia system were even more positive, with twenty one students enjoying using it "very much" and four "quite a lot". The single most significant reason, which was given by nine students highlighted the aspect of choice as her reason:

> *You were allowed to choose anything you wanted to do.*

Ruth emphasised the perceived learning gains from using the system:

> *I thought using the computer helped me learn my work better.*

When asked to reflect on what they had learned, Kate observed that:

> *We learned why graphs were the shape they were and how to read them.*

Philip noted that he had learned more about how computers can be used as aids for knowledge, not just games and further that:

> *The films showed and explained the graphs clearer than a text source would, or could ever do.*

Jacqui highlighted the advantages over text based media:

> *How to show what graphs really, mean instead of words in a book - you could see it in action.*

8.6.4 PRE-TEST, POST-TEST AND DELAYED POST-TEST

The pre-test, post-test and delayed post-test are included in Appendix 2 (i). In the event, only questions 1 and 3 were used from each of the papers. These questions on each paper asked for descriptions of graphs involving distance and speed against time respectively. The remaining questions were more open-ended, asking for sketches of graphs describing the pupils' own journeys to school each day, together with explanations. The quality and extent of explanations varied greatly with these latter questions and judgements on the degree of understanding conveyed were difficult to make. In contrast, questions 1 and 3 resulted in responses about which more clear cut judgements could be made. As a result the view was formed that these questions would provide for more reliable comparisons to be made, both between individuals and also between different points in time.

Pre-test	Post-test	Delayed post-test
7.43	12.48	11.65

Of particular interest are the individual marks of the pupils who are the subject of the video recording, which is reported upon in the following chapter. Their results were as follows:

	Pre-test	Post-test	Delayed post-test
Group 1:			
Laura	12	abs	8
Chantel	12	15	14
Claire	10	14	15
Group 3:			
Philip	8	15	8
Neil	5	8	4
Jonathan	13	11	13
Group 4:			
Joanne	0	11	10
Caroline	0	14	8
Vicki	5	13	9

In overall terms it can be seen that there is evidence of an increased level of understanding between the pre-test and the post-test. This decreases between the post-test and delayed post-test, but there was still a substantial overall increase between the pre-test and the delayed post-test in evidence. Further reference will be made to this data at an individual level in chapter 10.

9.0.0 CYCLE 3: ANALYSIS OF VIDEO TAPE TRANSCRIPTS

9.1.0 METHOD OF ANALYSIS

In adopting a detailed and qualitative approach to the analysis of the discourse in Cycle 3 of this study, a decision was taken not to analyse the data on the basis of pre-determined categories. Aspects of the approach taken by Hoyles, Healey and Pozzi (1994) were given careful consideration e.g. their development of a scoring scheme for levels of collaboration and involvement by individuals within the group. This approach was not taken, but instead an approach based upon the analysis of the discourse involved in the interaction was adopted. This was in contrast to that adopted by Hoyles et al, who regarded such an approach as impossible, in the context of their own project at that time given its scale and complexity. The methodology of Mercer (1991) and also Edwards and Mercer (1987) was particularly influential at this stage. It had the advantage of leaving the discourse untouched in the context of a process of progressive focussing, thus allowing for patterns and issues to arise from the data analysis itself. However this work was conducted in classroom situations in which the focus was mainly upon the interaction between teacher and pupil.

As a result of the initial transcription and analysis of the data some broad patterns soon began to emerge. In particular quite contrasting patterns of interaction became apparent between the groups. The discourse also drew attention to the development of the understanding of one pupil in particular. In reflecting upon the methodology adopted by Mercer, the need for some interpretive framework through which to analyse the data arising from peer interaction soon became evident. The approach adopted by Teasley and Rochelle (1993) was found to be particularly resonant with this study and was consequently adapted to form the chosen framework for analysis.

The approach and background to the study of Teasley and Rochelle are detailed more fully in earlier chapters of this study. However a summary of their framework is considered to be appropriate at this point.

9.2.0 SUMMARY OF INTERPRETIVE FRAMEWORK

A starting point for the development of their framework is Teasley and Rochelle's definition of *collaboration* as:

> Collaboration is a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem.
>
> (Teasley and Rochelle, 1993)

This definition reflects the perspective of the authors which is significantly influenced by the work of Vygotsky, in that it is based upon a view of learning as a fundamentally social activity i.e. that understanding is built through social interaction and activity and that concepts and models are social constructions.

The notion of "a shared conception of a problem" is a central one and this is used as the basis of what is described as a *Joint Problem Space*. It is proposed that social interactions in the context of problem solving activity occur in relation to a Joint Problem Space (JPS). This is defined as a shared knowledge structure that supports problem solving activity by integrating goals, descriptions of the current problem state, awareness of available problem solving actions and associations that relate goals, features of the current problem state and available actions.

This idea is developed further with the proposition that the fundamental activity in collaborative problem solving occurs by means of the engagement of the participants in an emergent, socially negotiated set of knowledge elements that together constitute a JPS.

A number of "structured discourse forms" are described which conversants use in everyday speech to achieve mutual intelligibility. These utilise language, bodily action and combinations of words and actions. It is proposed that students use the structure of conversation to continually build, monitor and repair a JPS. They also describe some *categories of discourse events* that they have used in their analysis such as turn taking, narrations and coordinations of language and action.

Turn-taking is the most pervasive and general category of discourse and can be made up of specific discourse units such as questions, acceptances, disagreements and repairs, which represent ways of taking a conversational turn. The flow, content and structure of turns can be used as a measure of the extent to which participants in a conversation understand each other.

Collaborative activity can produce periods of conflict in which individual ideas are negotiated with respect to the shared work. Attempts to reduce the conflict by resolving misunderstandings are a feature of a working style in which a shared conception of a problem is maintained. Such attempts are described as *repairs* and as such represent the method by which participants can deal with problems in speaking, hearing or comprehension of dialogue.

The notion of a *collaborative completion* describes an exchange which distributes a compound sentence over discourse partners i.e. one partner's turn begins a sentence or idea, and the other partner uses their next turn to complete it.

Narrations represent a verbal strategy that enables partners to monitor each others' actions and interpretations. Continued attention to narrations and accompanying action can signal acceptances and shared understanding, whilst interruptions create an immediate opportunity to rectify misunderstandings.

A major role of a computer in supporting collaborative learning can be in providing a context for the production of action and gesture, which can serve both as presentations and acceptances. The simultaneous production of matching language and action by separate partners can provide opportunities for acceptances of new ideas and also for repairs.

system was integral to the cycle of observation, reflection, recording, discussion and feedback which were the components of the multimedia-based group activity. The feedback from the system was crucial in confirming, or otherwise, group conclusions and performed the function of bringing episodes to a conclusion when successful choices had been made. This feature has therefore been highlighted as a part of adapted interpretive framework which was subsequently utilised.

9.2.0 ANALYSIS OF CYCLE 3 TRANSCRIPT DATA: EPISODES OF DISCOURSE

The initial viewing of the video recording of the multimedia-based small group work confirmed the impressions of collaboration and rich interaction, which were formed during the course of the classroom trials. However this was mixed with evidence of lower levels of collaboration and some quite superficial interaction. Extracts from the work of three of the four groups, which were recorded, have been analysed closely for the purposes of this study.

The first of these groups is made up of Laura, Chantel and Claire who provide evidence of collaborative interaction and joint problem solving activity. The second group comprises Philip, Neil and Jonathan, whose work as a group exhibited similar characteristics but also some distinct differences. Finally, in complete contrast, the interaction of Joanne, Caroline and Vicki is analysed to provide an example of a less successful collaborating group. All the groups which were recorded were single sex groups which reflected the friendship groups which were used as the basis for organisation for the majority in the class.

It was decided not to use the data relating to the fourth group comprising Matthew, Ryan and Philip as this was the shortest section of tape and all of the episodes contained involved a substantial element of intervention from a student teacher who was present during the classroom trials.

The episodes have been taken in the order in which they occurred and these are available in full in Appendix 2(ii). Where an extract from an episode has been used in the text, each utterance is numbered in order, from 1 onwards, so as to facilitate cross referencing. However these line numbers will not be present on the raw data contained in the appendix. Where the group members were interrupting each other or speaking simultaneously their contributions have been marked with a continuous vertical line immediately to the left e.g. | N:

9.3.1 LAURA, CHANTEL AND CLAIRE

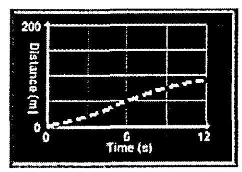
In the first episode to be transcribed, this group did not have very much success. There was some limited interaction but no real discussion about the problem and no sketching of graphs. The activity seemed to consist mainly of guess work, and that with little success, before the intervention of the teacher-researcher.

When viewing the second episode, it became clear that the group members were uncertain about the nature of the task. Chantel asked whether it is "just meant to be distance?" which provided the opportunity for the teacher-researcher to clarify one aspect of the nature of the task, relating to the fact that choices could be made about the axes.

The third and fourth episodes were essentially concerned with clarifying the nature of the task further and in ensuring capability in terms of controlling the software interface. This involved a considerable input from the teacher-researcher. The pupils were encouraged to think about and discuss their ideas about what the graphs might look like. They began to sketch their ideas as graphs and to use these to aid the discussion. By the time the group began to view episode 5 about the cheetah, they had established the means for interacting with the multimedia system and also seemed to have a clear understanding of the nature of the task set.

Group 1: Laura, Chantel and Claire
Episode 5: Cheetah (0.14.16)

1	L:	Do one that you want, cos like, well I did one.	Laura speaking to Chantel.
2	Ch:	Do Cheetahs. What do you two want?	
3	Cl:	Cheetahs.	
4	Ch:	Great. Play it.	
5	Cl:	Oh, speed against time.	
6	Ch:	Play it.	
7	Cl:	Play it.	
8	Ch:	Should we start on there? When it's cleared. Distance?	Bottom left hand corner of the screen.
9	Cl:	Is it distance against time we're doing?	
10	Ch:	Yeh, distance against time.	Sketching graphs.
11	L:	So it's starting off no distance and time.	Pointing to the origin.
12	Ch:	It goes - it gets faster.	
13	L:	That's right.	
14	Ch:	It'll go up like that, won't it?	
15	Cl:	Try that.	Up to this point Claire had been active in sketching the graph but did not take a turn from line 10. At this point the computer provided "correct" feedback and the full screen replay with graph overlay was played.

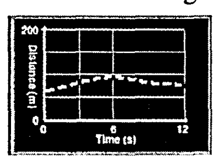


In this episode the group is viewing the sequence about the cheetah and are considering the graph of distance against time, although the clarification of the task only emerges part way through the episode . Laura initiates the discussion at line 1 by inviting Chantel to make the choice on this occasion. The turn taking between Chantel and Claire then flows smoothly down to line 11, although there is a significant gap between line 8 and 9 where they all appear to be reflecting and are sketching graphs. This section of the discourse relates to establishing the problem or JPS and setting the appropriate parameters on the computer system. Laura, who has been active in sketching her graph up to that point, then makes her suggestion that "it's starting off no distance and time", whilst simultaneously pointing to the origin of the graph shown on screen. Given that, of the two available graph options, this is the only one to go through the origin, Laura has drawn the

group to this crucial distinction between the two options.
This is accepted by Chantel, who offers another feature of the motion at line 12 by stating that "it gets faster". Although not directly relevant, it is almost instantaneously accepted by Laura and leads Chantel to complete this collaborative interchange with the question at line 14 that "It'll go up like that, won't it?". Before Laura has a chance to respond, Claire takes her turn to accept the analysis of the others by suggesting "Try that". Up to this point Claire had been concentrating on drawing her graph, having established the nature of the problem at line 9. However it would seem that she had been attentive to the interaction between Chantel and Laura, given the timing of her final contribution which, together with the feedback from the system, brought the episode smoothly to completion.

In the next section they are considering the graph of speed against time.

Group 1: Laura, Chantel and Claire
Episode 5: Cheetah (continued)

16	L:	Speed against time.	
17	Ch:	Speed against time.	
18	L:	So speed ...	
19	Ch:	It'll go up again, won't it? Like that.	Showing her sketch to the others.
20	Ch:	No! No! No! No! No!	Mistake made in sketching the graph - talking to herself.
21	L:	That were it.	Referring to the second graph option.
22	Ch:	Well he'd already started off speeding - hadn't he? He was slowing down, wasn't he? Like that.	
23	Ch:	Aye, like that!	Referring to the selected the graph.
24	L:	Yeh, test it.	
25	Ch:	Or that one.	
26	L:	Test that one!	Back to the initial choice above - sounds certain.
27	Ch:	He were already running, weren't he?	
28	L:	Yes!	Positive feedback received from the system.

In this second section of the episode Chantel interrupts Laura to make the first suggestion at line 19 that "It'll go up again won't it? Like that". At the same time she shows her sketch to the others inviting acceptance or repair.

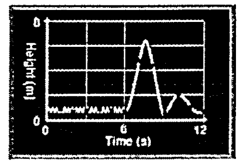
anyone else responds she takes the opportunity to repair her own understanding, as she realises that she has made a mistake, and at line 20 answers herself with "No! No! No! No! No!". This leads Laura to suggest the graph on screen as being appropriate. Chantel's response at line 22 provides an explanation for the graph being the shape that it is - she reasons that "he'd already started off speeding" and that "he was slowing down". At this point it is clear that Chantel is engaged with the problem and has followed the guidelines of the task in sketching the graph and in justifying her ideas. It is also the case that all the interactions in this second section are solely between Chantel and Laura, with Claire not participating in an active way.

A particular feature to emerge from the analysis of this data is the pattern of Chantel's utterances. It would seem that Chantel is instrumental in giving a lead to the collaboration throughout this episode, by the way in which she combines her assertions with a question inviting acceptance or repair. Over the course of this episode Chantel asks seven out of a total of eight questions which are posed. Of these five are of the form "wasn't he"/"won't he" etc and are linked to a preceding statement. For example at line 22 she offers two statements with questions attached:

> *Well he'd already started off speeding - hadn't he?*
> *He was slowing down, wasn't he?*
> *Like that.*

She also responds to her own question at line 23 on seeing the selected graph! This leads to an acceptance from Laura at line 24 with a suggestion to test it. At line 25 Chantel then appears to be thinking aloud which results in a much firmer suggestion from Laura to "Test it!". Having received positive feedback from the system, Chantel is still very much engaged with the problem and offers the explanatory observation that "He were already running" together with the linked invitation to accept this suggestion in the form "weren't he?". This is responded to positively by Laura.

Group 1: Laura, Chantel and Claire
Episode 6: Pole vault (0.18.30)



1	Ch:	He's travelling - up, isn't he?	Graph on screen.
2	Ch:	And he gets faster. So it's not that.	
3	Cl:	So it ... mm ... it would go up, wouldn't it and it would drop down like that?	Showing her sketch to Chantel.
4	Ch:	Yeh.	
		(unclear exchanges)	
5	Ch:	It would go up and just across ... a bit slanted a bit.	Taking turns to complete each others sentences down line 9.
6	L:	No! No! but no! but because it's ... look it's distance against time right? He's running first, isn't he?	Referring to her sketch.
7	Cl:	Yes, and he's still travelling when he pole vaults.	Holding up her sketch for the others to see.
8	L:	Yeh but he's going, he's going ...	
9	Cl:	Slower.	
10	Ch:	He's not going a right long distance, is he?	
11	L:	No.	

Chantel characteristically begins this episode with an assertion followed by an invitation for acceptance or repair. She immediately follows up her first utterance with the additional statement at line 2 that "He get's faster" which leads her to state her rejection of the graph on screen. She does not elaborate on her statement "So it's not that". However a clear link is made between the fact that he is getting faster and that the currently selected graph does not illustrate such motion. This enables Claire to take her turn by elaborating on what the graph should look like when, at line 3, she comments that "it would go up, wouldn't it?". In this utterance, Claire uses the technique previously used by Chantel to link an assertion with a follow-up question inviting an acceptance or repair. Chantel takes her turn at line 4 to accept Claire's suggestion.

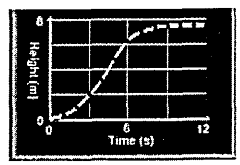
At line 5, Chantel appears to begin to describe the "correct graph". However at line 6, Laura appears to reject Chantel's suggestion. She and invites acceptance with the follow-up question: "right?". She then asserts that "He's running first" together with an invitation for acceptance. Claire now takes her turn to accept Laura's suggestion at line 7 and begins to "repair" the shared understanding of the problem by adding "and he's still travelling when he pole vaults". Laura accepts the suggestion at line 8 and begins a further statement "but he's going, he's going ...", which is subsequently completed (a *collaborative completion*) by Claire with "slower". This is not rejected by Laura and in fact is an accurate description of the motion, during the actual pole vault itself, following the initial run up. Chantel offers a further contribution at line 10, once again with an invitation for acceptance which is taken by Claire at line 11. The episode then continues as follows:

Group 1: Laura, Chantel and Claire
Episode 6: Pole vault (continued)

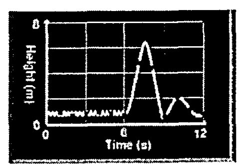
12 Cl: Yeh it'll go like that. — Sketching the graph.

13 L: No, go through the graphs. — Pointing to the right-hand dialogue box (as opposed to the one for choice of axes)

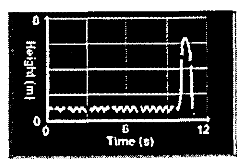
14 Cl: · Yeh that. — Graph 1.



15 L: Wait, try another one.
No not that one. — Graph 2.



16 Cl: Oh it could be that yeh. — Graph 3



17 L: No not that one. — Pointing to the graph 3.

18 Cl: How do you ... ?

19 L: Because he's going across there, isn't he? — Now pointing to graph 1.

20 Ch: That! That one I think. — Referring to graph 1.

21 L: Yeh. Test that one!

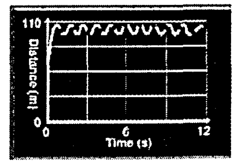
22 L: Yes! — Positive feedback from the system.

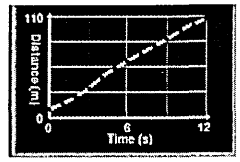
Claire continues the episode by sketching a graph about which she feels sure enough to suggest "it'll go like that", at line12. However this suggestion is rejected by Laura at line 13, who offers an alternative suggestion to "go through the graphs". Once again Claire makes a suggestion, "Yeh that", at line 14, which is in fact correct. However Laura asks her to "wait" and "try another" at line 15, rejecting graph 2 immediately. Seemingly as a result of this interchange, Claire becomes uncertain and suggests that it could be graph 3. This suggestion is immediately rejected by Laura at line 17. Claire appears to begin to ask for an explanation at line 18 and without waiting for her to complete the sentence, Laura points to the section on graph 1, which shows him "going across". Chantel, who has said little since making her suggestion at line 5, but who seems to have listened carefully to the others, now makes the well timed assertion at line 20: "That! That one I think". This is immediately accepted by Laura with her suggestion to test it, followed by the resulting positive feedback from the system.

It would appear that Chantel had decided, quite early in this episode, which was the correct graph. However, Laura appeared to spend the early period sketching her own ideas and subsequently seemed to need to evaluate all the options available on the system. This may have led to Chantel standing back whilst Laura went through this process. Meanwhile Claire, who appears as the least forceful in the group, seems to lose some of her initial confidence through the interaction with Laura, who is quite forceful in her rejection of some of Claire's suggestions.

In the next episode the group is considering the hurdles:

Episode 6: The hurdles (0.24.50)



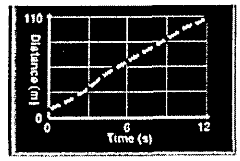


1	Cl:	Well the speed is something like that ...	Graph 1 showing on screen.
2	Ch:	It just goes up, like that.	
3	Cl:	Yeh. Right, try it then.	
4	Cl:	Do you think it'll get to ...	
5	Ch:	No. It'll ... That one, it's that one.	Pointing to graph 2.
6	L:	That one?	
7	Ch:	It is.	
8	L:	That one?	Indicating graph 1.
9	Ch:	No. The one behind it.	
10	Ch:	That one.	Referring to graph 2.
11	Cl:	That?	
12	Ch:	You can ... he's going along the hurdles, isn't he?	Drawing a horizontal wave motion in the air.
13	Ch:	He'll be going at constant speed along the hurdles.	
14	L:	Yeh! Yeh! Yeh! That's right.	Positive feedback from the system.

Claire begins the interchange by suggesting that the "speed is something like that", with reference to her own sketch. This suggestion appears to be accepted by Chantel at line 2, who adds that "It just goes up, like that". At this time graph 1 is showing on the screen. Claire suggests trying graph option 1 but on toggling through the options to graph 2, Chantel appears to change her mind, at line 5. The interchanges with Laura, based upon her questions at lines 6 and 8 serve the purpose of clarifying exactly what Chantel is proposing. Claire's question "That?" challenges Chantel, who responds at line 11, using both language and gesture. She explains that he is "going along the hurdles" and makes a horizontal wave motion in the air. She also invites acceptance, in her characteristic way by means of "isn't he?". Before giving anyone else the chance to respond, she adds at line 13 that "He'll be going at constant speed along the hurdles". Here she makes a link between constant speed and the notion of "going along", which seems to convince Laura as she speaks, from her response to the positive feedback from the system at line 14.

In the final section from this episode the group considers the graph of distance against time.

Group 1: Laura, Chantel and Claire
Episode 6: The hurdles (continued)

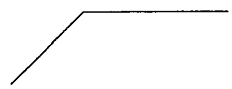
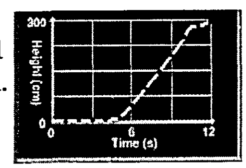
15	Ch:	Do the journey ... distance against time.	
16	L:	Yeh.	
17	Ch:	Cos it'll just go up, won't it? Like that. Like that.	Sketching the graph - Claire quite excluded.
18	L:	Yeh.	
19	Ch:	He'll just keep on travelling and going up like.	Referring to graph 2
20	L:	Like that?	
21	Ch:	Yeh.	Positive feedback from the system.

Chantel is once again instrumental in giving a lead to the group and is quite dominant in this final episode. She moves the group on to consider distance against time at line 15, receiving acceptance from Laura at line 16. She then describes the key feature of the graph at line 17 i.e. "it'll just go up". She characteristically invites acceptance and shows her sketch to Laura, whilst emphasising that it will be "Like that. Like that". This acceptance is gained from Laura at line 18, which leads Chantel to elaborate on her explanation further at line 19. In doing so she makes a link between the fact that "He'll keep on travelling" and the notion of "going up". Her utterance would suggest that he goes up, rather than the graph "goes up". This may account for Laura's question by means of repair to their shared understanding, when she asks, with reference to the graph, "Like that?". Chantel immediately responds in the affirmative and positive feedback is gained from the system.

A particular feature of this short interaction is the dominance of Chantel and the relative exclusion of Claire. Laura's role in her first two interactions is by way of affirming Chantel's thinking. However her question at line 20 would appear to be an attempt at "repair" in which the computer system serves to mediate the communication between the two.

are considering distance against time initially:

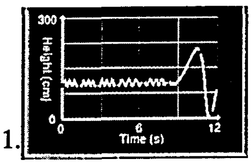
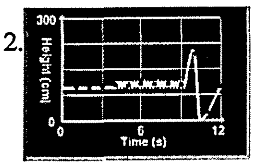
Group 1: Laura, Chantel and Claire
Episode 9: Long Jump (0.33.23)

			Initially all are sketching the graphs.
1	Ch:	Right. Right. She runs, doesn't she?	
2	Cl:	Yeh.	
3	Ch:	And then I bet she stays, I mean, at that speed. And then she jumps.	
4	Cl:	Which height?	
5	Ch:	No, so that means she stops doesn't it?	
6	L:	But it's not distance, it's not height. It's distance not height.	Correcting what she meant to say.
7	Cl:	It goes erm ...	
8	Ch:	It goes up.	
9	Cl:	It doesn't go ... ?	
10	Ch:	Then it goes at (*constant?*) speed.	Mapping out this shape with her hand. 
11	Cl:	Shall I try it?	
12	Ch:	And then it stops like that.	Referring to her sketch.
13	Ch:	That!	Pointing to graph option1 and adjusting her version. (seems sure) 
14	Cl:	That? Try it?	
			Correct feedback given from the system and the motion is played with graph overlay. It is watched especially closely by Chantel, who maps out the graph with her hand.
15	Ch:	See she ...	Pointing to the section when the distance is shown to be constant.
16	Ch:	Right.	

At the start each individual in the group is engaged in sketching out her own ideas on paper. This is a characteristic of the way in which this group functions throughout, as is the way in which Chantel gives a lead to the interaction, as she does once again on this occasion. She begins by asserting the simple observation that "She runs" and invites acceptance by following up with "doesn't she?". Claire takes her turn to confirm acceptance and Chantel ventures further at line 3 with two ideas. Firstly she suggests that "she stays ... at that speed", which may be referring to the notion of constant speed. Secondly she suggests that "then she jumps" which implies an order i.e. firstly she travels at constant speed and then she jumps. Claire's utterance "Which height?" at line 4 seems entirely unrelated to anything that has been said previously and is in fact ignored by Chantel, at line 5, who continues with her own train of thought. She asserts that "so that means it stops" and invites acceptance with "doesn't it?". Laura's response at line 6, on first reading, appears to be confused and unrelated to the previous discourse. In fact her utterance is in response to Claire's question at line 4 and comes in the form of an attempt at repair. However she does not say what she intended and has to correct herself in conveying that "It's distance not height." Claire then begins to make a statement at line 7, which Chantel repeats and completes at line 8, when she states that "It (*the graph*) goes up". Claire then begins a question at line 9, but is again interrupted by Chantel, who who uses both language and gestures to show that "it goes at constant speed". By this stage Claire is willing to concede to Chantel and asks "Shall I try it?". Chantel does not appear to respond, but instead narrates her thinking aloud as she interacts with system. At line 12 she continues her explanation of the graph, when she states that "then it stops like that", with reference to her own sketch showing the section of the graph as it flattens out. At line 13 Chantel recognises the necessary adjustments to her own sketch, from viewing the available graph option, and seems sure in her selection of graph option 1. Claire responds by testing this option despite receiving no direct response from Chantel and the system provides correct feedback. At this stage Chantel is totally engaged with the problem and she appears to carry the other group members with her, as she maps out the graph with her hand and points to the final section of the graph, which displays the period after the jumper has landed.

In the final section of this episode the group is engaged in the consideration of the graph of height against distance.

Episode 9: Long Jump (continued)

17	Cl:	Shall we do height?	
18	Cl:	Height against distance?	
19	Ch:	Height against distance.	Individually sketching graphs.
20	Ch:	So it'll just ... whatever height she's doing ...	
21	|Ch:	It'll be like that.	
22	|Cl:	Go up and down.	All looking at Claire's sketch.
23	|Ch:	Then she'll go jumping like that.	
24	|Cl:	And she <u>lands</u> .. like that.	
25	|L:	And then jumps up again.	Laura showing her sketch to the other two.
26	|Cl:	Yeh like that.	
27	Ch:	And then lands again, doesn't she?	
28	L:	That! Oh! No! No! No!	Referring to graph option 1. 
29	|Cl:	That. That cos she ...	Referring to graph option 2. 
30	|Ch:	Yeh that.	
31	|Cl:	... she don't run at first.	
32	L:	No! No! No!	Incorrect feedback given (unclear exchanges). Correct option chosen but reasons why it was one rather than the other not discussed, due to lack of time as the lesson was ending.

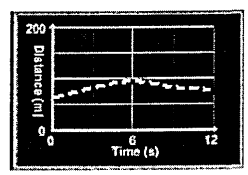
Claire initiates the activity on this occasion by asking for confirmation of the focus of the problem. This is confirmed, after Claire's clarification at line 18, by Chantel's reply "Height against distance" at line 19. Once again Chantel initiates the discussion about the problem itself. She begins, at line 20, by making a reference to the height and then much more clearly at line 21 asserts that "It'll be like that". This assertion seems to be related to Claire's sketch - with Claire herself adding almost simultaneously that it will "Go up and down". Between line 23 and 26 there is very rapid exchange between all three members of the group. Chantel refers to her going "jumping like that", Claire to her "landing ... like that" and Laura to the fact that she "jumps up again". The incorrect option, from two very similar graphs, is in fact chosen which elicits Laura's response at line 28. At line 29 Claire confirms that it is graph option 2 and begins to explain why. Her explanation is interrupted by Chantel's acceptance with "Yes that", but she continues by drawing attention to the fact that "she don't run graphs that they are choosing from. The response time shows clearly on the graph of height against time, as a smooth horizontal section of the graph. Although positive feedback is eventually achieved from the system, the discussion is not pursued, which may reflect the fact that it was simply the end of the lesson.

9.3.2 PHILIP, NEIL AND JONATHAN

The second group to be considered comprises Philip, Neil and Jonathan, who are considering the cheetah in this first episode.

Group 3:Philip, Neil and Jonathan
Episode 2: Cheetah (0.49.15)

1	IP:	It starts off slow.	
2	IN:	It starts off slow, gets really fast and then it ...	
3	IP:	It stops.	
4	IN:	... stops.	Neil laughs at them speaking simultaneously.
5	N:	That'll be what it's like.	
6	J:	What?	
7	N: .	See what it'll be like.	Jonathan leans over to Neil.
8	P:	Yeh. That's what it'll be like there. Wait. Check the other one Neil. Go on the arrow.	Pointing to graph 1 on the screen. Pointing to the arrow on the screen for Jonathan.
9	J:	This one?	Showing graph to Philip.
10	P:	No. Yeh.	
11	N:	It slows down for its pounce. Like that.	Looking at Jonathan.
12	P:	Yeh like that.	
13	N:	It's my view. Ah! I got it right didn't I? (laughs)	



Philip initiates the discussion in this episode by beginning to narrate his analysis of the actual motion. This prompts Neil to do the same at line 2, repeating Philip's utterance "It starts slow" and continuing the analysis with the statement that "(It) gets really fast and then ...". This has the effect of cutting short Philip's initial statement. However Philip interjects at line 3 with the statement that "It stops", in the form of a collaborative completion of Neil's utterance. At the same time Neil completes the utterance which he began at line 2 with "... stops" at line 4. At this point Neil laughs, in response to them both saying the same thing at the same time.

At line 5, Neil takes his turn to assert that "That'll be what it's like", as a result of studying the graph option on the screen. However Neil provides no explanation, nor has the problem been previously defined and agreed i.e. it is not clear whether the group is considering distance against time or speed against time etc. The initial exchange between Philip and Neil centred on the speed of the cheetah and from this they seem to have developed a shared understanding that the problem is about the graph of speed against time. However Jonathan's utterance at line 6 of "What?" seems to suggest the need for some shared understanding of the problem or of some definition of what "it" (the problem) actually is on his part. Jonathan's question is not addressed and Neil persists, at line 7, with the suggestion to "See what it'll be like". This is supported by Philip at line 8, who also asks Neil to check the other available options. Jonathan's only further contribution comes at line 9 when he asks "This one?", by way of confirming which graph Neil has in fact chosen. Neil and Philip then proceed to confirm the chosen graph, although they do not seek feedback from the system.

It is interesting to note that, in this episode, there is evidence of collaboration, with a collaborative completion occurring between Philip and Neil at the start. However a JPS is not established between all members of the group. Jonathan is clearly uncertain about the nature of the problem itself and his utterances are aimed at seeking clarification. In relation to the JPS, this clarification is not achieved for Jonathan up to the end point of this section of the episode.

Subsequent teacher intervention revealed that the group did not have a clear understanding of the nature of the software interface. In particular there was a need to clarify the process for selecting a different choice of axes and also the process for testing the chosen option, in order to gain feedback from the system.

The intervention is illuminating with respect to the way Neil expresses his thinking in particular. This next section begins with Jonathan and Neil's responses to the question posed by the teacher (participant observer in this case), about what the graph of distance against time might look like:

Group 3:Philip, Neil and Jonathan
Episode 2: Cheetah (continued)

12	|J:	It's going to go up like that.	Jonathan sketches it out in the air.
13	|N:	Well its ... distance. Distance there?	
14	|BH:	Distance against time. Yes.	
15	N:	Distance is ... It goes up - the distance doesn't it? Well like along. Time.	
16	BH:	What's happening to the distance?	
17	P:	It's getting greater.	
18	N:	It's going up. Higher.	

Jonathan uses language and gesture to describe the graph "going up", at line 12. Neil seems to be unsure at line 13, which results in a confirmation, at line 14, that the problem is about distance against time. Neil continues to appear to be confused in his thinking at line 15 when he takes his turn to assert that "It goes up - the distance", seeking acceptance or confirmation with the question "doesn't it?". He continues with the utterances "Well like along" and "Time". From these utterances it would appear that Neil is very confused in his thinking. This elicits an attempt to clarify matters at line 16, with the question "What's happening to the distance?". Philip replies correctly that "It's getting greater". However Neil's response suggests a confusion between the graph itself, which is indeed *going up* the page, and the actual distance which is *increasing*. This lack of distinction, between the motion itself and its abstract graphical representation, is a feature of Neil's thinking that subsequent data analysis will illuminate further.

In the next episode the group is considering the High Jump:

Group 3: Philip, Neil and Jonathan

Episode 3: High Jump (0.53.34)

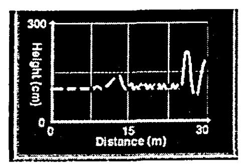
1	P:	Go on pick what you want.	To Jonathan (in control of the mouse)
2	N:	Plane. Not had a look at that one. Aeroplane.	
3	J:	I thought I could choose what I want.	
4	N:	O yeh. I'm sorry. Of course you can.	
5	J:	High jump.	
6	P:	Doing height against time still?	
7	N:	Height against time?	
8	P:	She starts off slow.	
9	N:	She has to start height, time, height ...	Neil looks puzzled.
10	|J:	She starts like that.	Making a wave motion in the air.
11	|N:	She goes like that.	
12	|J:	Because she ... like that.	
13	|N:	Like that. That's what I'd say.	Looking at his sketch.
14	J:	Yeh but she goes like that when she's running.	Making a wave motion again.
15	P:	Yeh but then it'll go down again, won't it?	
16	N:	(Laughs)	
17	P:	Yeh ... try the other one.	Pointing to the screen.

The initial exchanges in this episode are concerned with the social relationships of individuals within the group and issues of choice and control, rather than the establishment of a JPS. Neil's enthusiasm seems to be perceived by Jonathan as an attempt to dominate and to monopolise the choice of what to look at next. His statement at line 3 elicits an apology from Neil and enables Jonathan to make his choice of the High Jump. Once again Philip initiates the discussion in relation to establishing a JPS, with his question to clarify the focus at line 6: "Doing height against time still?" Although Neil takes his turn to repeat Philip's question there is no response, which seems to be taken as general acceptance. Philip initiates discussion related to an analysis of the motion at line 8, when he says that "She starts off slow". Neil displays confusion at line 9 when he says that "She has to start height, time, height ...". This leads to Jonathan taking his turn at line

16, with an attempt at repair of the shared understanding, which he uses language and gesture to describe the motion. He refers to her "starting like that", whilst making a wave motion in the air. Neil then takes his turn to repeat Jonathan's statement almost exactly, referring to her "going like that", at line 11. Neil's statement at line 13 that it is "Like that", with reference to his sketch, leads to Jonathan elaborating on his statement. He adds "when she's running", at line 14. This prompts Philip to add that "then it'll go down again" at line 15. Philip also invites acceptance with the follow-up question "won't it?". Neil finds something amusing which prompts a laugh and Philip then takes his turn again, at line 17, to suggest that they "try the other one", whilst at the same time pointing to the screen. The episode then continues as follows:

Group 3:Philip, Neil and Jonathan
Episode 3: High Jump (continued 1)

18	N:	What's that? Speed against time?	
19	P:	No. I mean the other thing.	Philip leans over and takes control of the mouse whilst Jonathan is busy sketching.
20	N:	Height against time? What's that?	
21	J:	That's height against time. That's it.	Looking at the graph.
22	N:	That?	
23	J:	That's it. That is it! Yeh!	
24	P:	Yeh. She runs along.	
25	J:	She runs and she goes like that.	Making a wave motion in the air.
26	P:	She jumps. She falls and then she stands up again, doesn't she?	Pointing at the graph on the screen.
27	N:	What's that for then?	Neil points to the first small hump in the graph.
28	J:	Look. Right.	
29	N:	Just play it again. Have a look.	
30	J:	No. She'll set off. She runs like that. Then she does a jump. Then she starts going like that (bouncing) and then she ...	



At line 18, Neil's question draws attention to the fact that the axes have been changed to speed against time. This was in response to Philip's suggestion, at line 16, to "Try the other one". In fact the wrong option was changed and Philip takes his turn, at line 19, to point this out with the statement "No. I mean the other thing". At the same time he leans over to takes his turn, at line 20, to draw attention indirectly to the fact that the axes have been reset, by his question "Height against time?" which he follows up with "What's that?". This question provides Jonathan with the opportunity to confirm that it is height against time and also to add "That's it", by which he means the graph which describes the motion. Neil's further utterance, at line 22, of "That?" provides a further opportunity for Philip to emphasise "That's it. That is it! Yeh!"

Up to this point, in this section, there has been no explanatory discussion, as the discourse has focussed upon a clarification of the axes and also on the solution. However Philip initiates such discussion at line 24 by "reading" the graph in terms of the actual motion. He begins by stating that "She runs along". This prompts Jonathan to intervene at line 25 and continue that "She runs and she goes like that". At the same time Jonathan makes a wave motion in the air to signify the up and down motion of her initial run-up. Before Jonathan has paused for breath, Philip completes the train of thought at line 26 by stating that "She jumps. She falls and then stands up again". Once again he invites acceptance, in the same way as was characteristic of Chantel in group 1, by adding "doesn't she?" During this interaction there is a high level of excitement and, although it is not distributed over a single sentence, the interaction between Jonathan and Philip as a whole could be seen as a collaborative completion *of a particular line of thought.*

Neil's intervention, at line 27, seeks clarification of a particular feature of the graph. This is in the form of a small hump at the start of the approximately horizontal motion. Jonathan refuses Neil's suggestion at line 29 to "Just play it again" and instead seeks to explain it to Neil, at line 29. He correctly points out, at line 30, that she does in fact start with a little jump before commencing her initial run up.

The group continues to analyse this particular aspect of the motion in the next section of this episode:

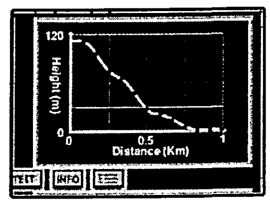
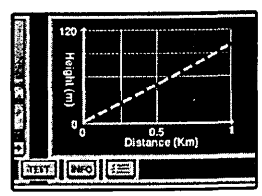
Episode 3: High Jump (continued 2)

31	N:	Why does she do a jump?	
32	J:	Play it!	
33	P:	Test! Test! See.	
34	J:	Watch!	
35	N:	Let's have a look at this ...	
36	N:	Oh alright, well she stands up again, so that can go like that.	Referring to his own sketch.
37	P:	Look.	
38	N:	Let's see her do her little <u>jump</u>!	
39	P:	She starts off running. Look there!	
40	N:	Oh! I thought ...	
41	P:	She runs along. Jumps up.	
42	J:	Aargh!	
43	N:	I thought it was from when she starts to move. Eh up!	
44	N:	I thought that when she starts to move she does a little hop and then carries on moving.	Tracing the path out on the blank screen.
45	J:	Rubbish. Told you!	All laugh.

Neil's question at line 31 of "Why does she do a jump?" is interpreted by Jonathan as doubting the validity of part of his analysis at line 30. His response is to "Play it!" at line 32 and Philip takes his turn at line 33 to be even more emphatic in his demand to "Test! Test!" and to "See". Jonathan continues the exhortation with his command to Neil at line 34 to "Watch!". Neil's good humoured response, "Let's have a look at this ...", at line 35 seems to suggest a willingness to reconsider. He appears to make a concession to the others at line 36, but clearly Philip is not satisfied and again exhorts Neil to "Look", at line 37, with reference to the feedback from the system. Neil's response at line 38 of "Let's see her do her little <u>jump</u>!" is said scathingly and it is clear that Neil is not at all convinced. This challenge sparks off a quite intense and excited exchange, which Philip begins with a commentary on the video of the motion as it plays. At line 39, he observes that "She starts off running" and Neil is exhorted to "Look there!". Neil seems to begin to climb down at line 40, but is interrupted by Philip's continuing commentary. At line 41 Philip makes the crucial observation, which fits with his interpretation of the graph, that she "Jumps explains why he thought that she did not "do a jump" at lines 43 and 44. His reasons seem to be associated with his recall of the actual motion, rather than being based upon any analysis of what the graph displayed. There is further triumphalism from Jonathan, at line 45, in response to Neil's explanation of "Rubbish. Told you!" This is received with good humour, in the spirit that seemed intended, and they all laugh.

The third episode to be considered, involving this group, is concerned with the sequence showing the aeroplane landing:

Group 3: Philip B, Neil and Jon'n
Episode 4: Aeroplane (0.58.18)

1	P:	It doesn't start off ... Watch this. Height against time.	Philip runs the video.
2	N:	Speed against time that.	The axes are set on height against time.
3	P:	Yes but no. We've got to choose which height against time is the right one.	Trying to clarify the task.
4	J:	Let's have a look.	Referring to graph option 1. 
5	N:	Yah! Oh! How come it does all the wavy lines? It goes straight down. It doesn't go up and down does it?	Making a diagonal downward wavy motion. Making a diagonal downward smooth motion.
6	J:	Well change it! Have a look ...	
7	P:	No but the nose goes up, doesn't it?	
8	N:	No! That's not it!	
9	J:	That's not it!	Referring to graph option 2. 
10	N:	It's taking off that, isn't it?	

Philip is very much in control at the start of this episode. At line 1, he is identifying the problem as being about height against time. However Neil takes his turn by responding to the video with the observation at line 2 that it is "Speed against time that". Philip's response at line 3 is interesting, because initially it appears to be contradictory. He replies "Yes but no". By this he may have been indicating that, "yes", the *graph* showing is the correct choice to fit the speed against time axes but that, "no", it is not addressing the current problem which is "to choose which height against time is the right one." In doing so, Philip is attempting to clarify the task, i.e. to establish the JPS. Jonathan takes his turn to try to move progress with the task itself, when he suggests at line 4 "Let's have a look".

Neil's response to the video sequence at line 5 would seem to be based upon an expectation of a smooth line, which probably reflects the more simple models from his past experience. However Philip does show considerable insight, ability to analyse the motion and to interpret the graph, in his observation at line 7 about the nose of the aeroplane going up on landing. The final comment in this section from Neil, at line 10, displays evident confusion between what he interprets from the graph and what he observes by watching the video sequence, which is clearly of the plane landing. The fact that the graph is rising from left to right suggests to Neil that this is the flight path of the aeroplane taking off. This confusion in his thinking was apparent earlier during episode 2, when in response to a question about what was happening to the distance covered, Neil's reply was:

> *It's going up. Higher.*

This was in contrast to Philip who answered:

> *It's getting greater.*

It would seem that Neil's misconception is related to the fact that he is describing the picture that he sees on the page i.e. "It (*the line*) is going up (*the page*). Higher (*up the page*)". The inability, at this time, to distinguish between the representation of the motion pictorially and the motion itself would explain why Neil interpreted graph 2 as showing the aeroplane taking off.

The next section is a later part of the same episode when the group is considering distance against time.

11	J:	Do you want to change that one?	Referring to the choice of axes.
12	P:	Yeh, I've done that. It's distance against time now.	
13	N:	Distance is going down? No! How could it be going down - distance? Oh, it's just landed. But its time's going up!	
14	| P:	What?	
15	| J:	The distance? It can't ... can't ...	
16	| N:	... go down. It just goes up.	
17	| P:	I know it can't.	
18	| N:	So, why does it look like that then?	Looking at graph option 2.

Jonathan's question at line 11 is an attempt at clarifying the nature of the task. Philip responds directly by indicating that he has chosen the axes to be considered and elaborates further, by way of clarification, that "It's distance against time now". Neil's stream of utterances at line 13 form a narration of his current thinking, which once again appears to be very confused. He seeks to interpret the graph in terms of the possible motion of the aeroplane. His first utterance relates to a perception of the distance *going down* rather than decreasing. He seems to dismiss this as a possibility but then refers to the fact that the plane has "just landed". By prefixing his sentence with"Oh", he seems to imply that the distance *going down* might be linked with the plane landing. This might suggest a confusion between the height and the distance (*going down*). However the notion of going down in this case seems to have been transferred from (going down) the page to (going down) in mid-air. The evident inability to distinguish between the abstract graphical representation and the motion itself would be consistent with his confusion. He concludes with the utterance "But its time's going up!" which seems to emphasise his state of confusion.

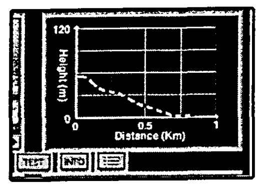
In response, Philip simply asks "What?", at line 14, and Jonathan attempts to repair the understanding, at line 15, by beginning to suggest that the distance can't decrease. However Neil does not allow him to finish and completes his sentence for him with "... go down. It just goes up." Although this completion is distributed over a single sentence, there is

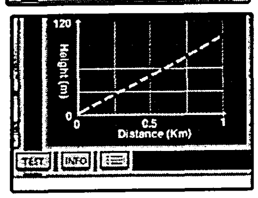
Although Jonathan does not protest, it is not clear that he would have used the same words as Neil, and Neil's use of language seems to be a major contributory factor towards his state of confusion. In fact Philip intervenes at line 17 and asserts that "I know it can't (go down)" which elicits the question from Neil "So, why does it look like that then?".

The interaction continues as follows:

Group 3: Philip B, Neil and Jonathan
Episode 4: Aeroplane (continued 2)

19	P:	Cos it starts from the bottom and goes up.	"It" referring to the graphical representation as opposed to the motion.
20	J:	Look the distance is there ...	Pointing to mid-air.
21	P:	But that's not it, is it?	Referring to graph option 3.
22	N:	It's not that.	
23	P:	That is ...	
24	N:	No.	
25	P:	It's got to be that.	
26	J:	That's distance ...	Referring to graph option 2.
27	P:	Test it.	
28	N:	It is right. Because distance goes up and so does the time, at the same time. Well done! (laughs)	Positive feedback received from the system.





Philip responds directly to Neil's question at line 18 by referring to "it" starting "from the bottom" and "going up". In doing so, it is clear that Philip is referring to the graph. This is in contrast to Neil's use of the term "it". For example in line 13 he uses "it" to refer to at least two aspects - firstly he uses it to refer to the distance, then in the following utterance refers to the aeroplane and finally talks about "its" time going up. Jonathan again attempts to repair the understanding, seemingly for Neil's sake, at line 20, by using language and gesture to clarify "the distance". Lines 21 to 24 concern the correct choice of graph and, by line 25, Philip appears certain, when he says that "It's got to be that". Jonathan seems to confirm the choice at line 26, Philip suggests they "Test it" and Neil subsequently confirms that "It is right", as positive feedback is obtained from the system.

His final utterances concern an explanation for the graph being "right". He remarks that "The distance goes up and so does the time, at the same time." Although this statement is not expressed in mathematically correct terms, it is correct if "it" is perceived simply as the picture of the motion on the page. Neil's statement would reflect an accurate description of the abstract representation but would not be an accurate description of the motion itself.

9.3.3 JOANNE, CAROLINE AND VICKI

The third group is made up of Joanne, Caroline and Vicki, who had sought help from one of the student teachers on the use of the software during their first episode involving the sequence on the pole vault. The extract involving the interaction with the student teacher is detailed in the following example of classroom discourse:

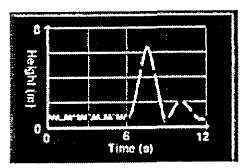
Group 4:Joanne, Caroline and Vicki
Episode 2: Pole vault (1.28.08)

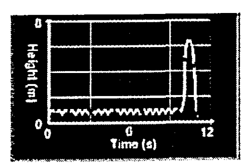
1	J:	Sir, we're stuck. We can't get the graph to plot on it.	
2	C:	We can't get it to plot what it 's showing on the screen.	
3	ST:	What are we doing? What sport are we doing?	
4	J:	Pole vault.	
5	ST:	Pole vault. Right.	
6	C:	We're wanting it to plot the graph while it's playing.	
7	ST:	And we're plotting distance against time? Right?	
8	|J:	Yeh.	
9	|V:	Yeh.	
10	|C:	Yeh.	
11	ST:	So let's go through the graphs. Right. Let's look at the next one then. And you can't find one of those? Why don't we try changing this one here? Try that. Change. Let's see what will happen. Right. Height against distance. Right!	 Pointing to the axes selection option.
12	V:	*(attempting to ask a question)*	

At the start of the episode Joanne and Caroline indicate that the group is having difficulty in "getting the graph to plot" at line 1 and "to plot what it is showing on the screen" at line 2. The student teacher first seeks clarification of the nature of the episode, which is confirmed at line 5. The choice of axes is then confirmed as distance against time at lines 7 to 10. However at line 11 the focus of the problem is arbitrarily changed by the student teacher to height against distance. This follows the change in the choice of axes on the screen. An attempt by Vicki to intervene is blocked and the episode continues as follows:

Group 4:Joanne, Caroline and Vicki
Episode 2: Pole vault (cont'd)

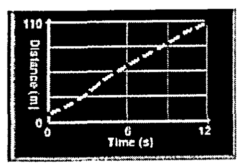
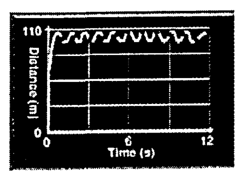
13	ST:	Woh. Woh. Woh. Let's consider what's happening here. When the man does the pole vault, right? ... he runs along the runway ...	
14	J:	That's what we've done already ...	
15	ST:	Yes?	
16	C:	Then he jumps.	
17	J:	He jumps, goes up, comes down ...	
18	ST:	Up in the air. Lands on that big floppy cushion ...	
19	J:	And rolls off it ...	
20	ST:	... and bounces back up again.	
21	J:	That's what we thought.	
22	C:	That's what we thought.	
23	ST:	So try that one.	Pointing to graph option 1.
24	J:	But we couldn't get it to plot ... probably because of that.	Referring to the message "Incorrect combination" on screen.
25	ST:	Incorrect combination? So let's have a look at the next one then. Try that one then.	Pointing to graph option 2.
26	ST:	Right. So change ... erm ... then after you've marked that ... change your ... erm ... axes and then we'll do it again. OK?	Correct feedback from the system.
27	C:	Yeh.	All sketching graph from the screen.





Having changed the focus of the problem to one that he seemed comfortable with, the student teacher began to analyse the motion at line 13, ignoring Joanne's attempt to explain that they had already done this and answering this analysis between lines 16 and 22, leading to the suggestion by the student teacher to "Try that one". This suggestion is made, however, without any reasons for doing so being articulated. Joanne explains that they could not get the graph to plot "probably because of that", which was the message from the system indicating that an "incorrect combination" had been chosen. The response from the student teacher, at line 25, is simply to look at the next option and to "try that one then". Again no reasons for making this choice are given and, although correct feedback from the system is now achieved, there is no analysis or discussion about why this is so. The pupils copy the "correct graph" from the screen as the student teacher departs and then discuss the next episode, without seeming to have really understood the problem or to have fully controlled the software.

Group 4:Joanne, Caroline and Vicki
Episode 2: Hurdles (1.34.40)

1	V:	What should we do?	
2	J:	Do ... hurdles.	
3	C:	Full screen. We can watch it first.	
4	C:	Right go back to the small screen. Let's have a look at the choices.	
5	J:	It's not that one.	Referring to graph 1. 
6	J:	It's that one. It's that one.	Referring to graph 2. 
7	C:	Is it distance against time?	
8	J:	Yeh. Just check that.	
9	V:	Speed against time.	
10	J:	Speed.	
11	C:	Speed.	
12	C:	Just try to plot it with distance.	Very uncertain about how to change the axes - consult the Help Cards
13	J:	What are we doing? Just trying? Just trying?	
14	J:	Test.	
15	V:	Should I go on full screen?	
16	C:	Yeh if you like.	
17	J:	You can't have that ... we haven't got the graph on now.	

should we do?". In fact Vicki was in control of the mouse during the whole of the time that this group was working at the system. Joanne suggests "Hurdles" at line 2 and Caroline's suggestion, to play it in full screen first, forms an acceptance at line 3. After watching the video, Caroline suggests that they have a look at the choices, at line 4. At line 5, Joanne asserts that "It's not that one" and subsequently, at line 6, that "It's that one. It's that one". However the nature of "it" has not been discussed or previously agreed by the group i.e. the JPS has not been established nor has any discussion towards its establishment taken place. Caroline begins to try to clarify the nature of the problem at line 7, with her question "Is it distance against time?". Evidently Joanne thinks that it is, from her response at line 8. However, Vicki takes her turn to point out that it is speed against time. Both Joanne and Caroline repeat "Speed" at the same time and seem perplexed. Caroline seems to suggest changing the axes to distance against time, at line 12. However none of the group appears to know how to change the axes. Joanne seems disheartened and confused at line 13, when she asks "What are we doing? Just trying? Just trying?". She seems to answer herself at line 14 with "Test".

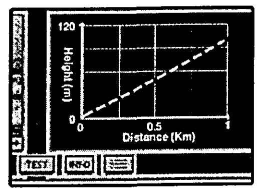
Given the failure to establish a JPS and also to fully control the software, it would appear that Joanne is ready to settle for just getting to the correct solution. Vicki's question at line 15 relates to a technical option with the software, rather than being concerned with the problem itself, which in fact is typical of the nature of most of her limited interaction. Caroline's response of "Yeh if you like", implies acceptance but seems to suggest that it is of minor significance. Joanne, however, protests at line 17 that "You can't have that ... we haven't got the graph on now". In fact the graph was being overlayed on to the full screen motion, but none of the group seemed to be aware of this. It was also the case that the axes were set to height against time and, by chance, they had matched up the correct graph although they seemed to remain unaware of this.

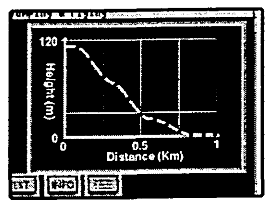
No discussion about the problem had taken place and there had been no progress in establishing, or even agreeing on the focus for, a JPS. A was successfully interacting with each other and with the system, and also that they were receiving positive feedback. However this close analysis does illuminate how misleading this impression would in fact be.

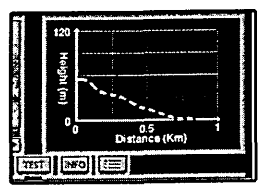
In this next episode the group is watching the sequence of the aeroplane landing.

Group 4:Joanne, Caroline and Vicki
Episode 3: Aeroplane (1.38.19)

1	C:	Height against distance, is it?	
2	V:	Yeh!	
3	C:	Or height against time?	
4	J:	Height against distance.	
5	C:	Height against distance.	
6	C:	What choices are there? Not that.	Referring to graph 2
7	C:	It might ...	
8	J:	It might be that.	Referring to graph 1
9	J:	Keep it still a minute! Is it that one?	Referring to graph 3
10	C:	It comes down gradually, doesn't it?	
11	J:	Is it going down or is it on the flat?	
12	C:	It's the plane landing.	
13	J:	I didn't know if were coming down or not.	
14	C:	Try that!	
15	J:	Test it! Yeh!	Still referring to graph 3.
16	J:	Do the cheetah!	Positive feedback from the system.







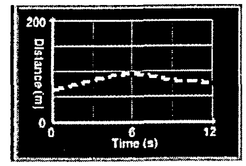
In this episode, Caroline begins by clarifying the focus of the task by asking "Height against distance, is it?". Vicki responds positively, but Caroline seeks confirmation, at line 3, which Joanne takes her turn to provide at line 4. Having confirmed the focus of the task, Caroline then seeks to consider immediately answers herself, by dismissing graph 2 but does not provide any reason for her rejection. At line 7 Caroline appears to begin to conjecture, by starting to say "It might ...", which prompts Joanne to interrupt by repeating her words and completing the sentence with "It might be that." Joanne then calls on Vicki to "Keep it still a minute!" and asks "Is it that one?", at line 9. Up to this point there has been no discussion of the motion or of the problem itself. At line 10, Caroline's attempt to analyse the motion can be seen as the start of the negotiation of a JPS. She remarks that "It comes down gradually" and invites acceptance by adding "doesn't it?". Joanne's question at line 11 of "Is it going down or is it on the flat?" allows Caroline to respond by explaining that "It's the plane landing".

The short exchange between Caroline and Joanne is in fact the only discussion which takes place about the problem itself. At line 14 Caroline suggests "Try that!" and Joanne echoes this at line 15 with "Test it!". In response to the positive feedback from the system, Joanne exclaims "Yeh!" at line 15 and immediately suggests that they "Do the cheetah!".

A particular feature of the interaction in this group is the minimal level of involvement of Vicki, although it is also interesting to note that she has control of the mouse throughout the entire time that the group was being recorded. In this last episode, her only contribution was to confirm the chosen graph option on the system. Another feature is the minimal level of discussion about the problem itself. For example, most of the discussion centres, initially, on defining the focus of the task and then on simply deciding which graph fits. There is no evidence of individual sketching of graphs or of any prior reflection. Another particular feature is that, on each occasion, the group only considers the axes which come up by default each time. So, for example, they did not consider the options of height or distance against time in relation to the aeroplane landing in this case. The opportunity to deal with the latter two issues did present itself when the student teacher intervened in episode 2, but this was not used effectively and in the next episode, concerning the cheetah, the overall level of interaction continues at a minimal level.

Episode 4: Cheetah (1.41.05)

1	C:	It's speed against time.	
2	J:	Is it speed? I think it's speed.	
3	C:	Try that.	Referring to graph 2
4	V:	This one?	
5	C:	Yeh. Just try that and test it.	
6	J:	Hey. Is that right? That's speed against time.	Positive feedback from the system.



Once again Caroline gives a lead in terms of clarifying the focus of the task, at line 1. Joanne then asks "Is it speed?", whilst looking at the graph option. She seems to be meaning to ask the question "Is this graph the correct option for speed against time?", at line 2. She seems to decide that it is correct and Caroline's response at line 3 is to "Try that". Vicki's question, at line 4, once again simply seeks confirmation of the choice, in order to execute this on the system. Caroline confirms the choice, at line 5, and the correct choice is confirmed by Joanne at line 6, following positive feedback from the system.

This general pattern of interaction is continued by the group in episode 5.

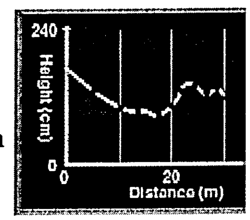
Group 4:Joanne, Caroline and Vicki
Episode 5. Long jump (1.41.05)

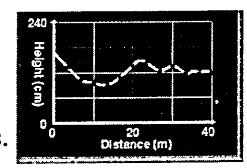
1	C:	Shall we draw it?	
2	J:	Oh no we'll draw it afterwards. Test it. Incorrect.	
3	V:	It's wrong.	
4	J:	So that means that that's wrong. It might not. It is. I suppose if it's distance, she's getting faster, isn't she?	Pointing to the choice of axes, rather than the choice of graph.

At line 1, Caroline asks "Shall we draw it?". Joanne's response is "Oh no we'll draw it afterwards. Test it. Incorrect". Vicki's only contribution in the entire episode is that at line 3, when she observes "It's wrong". They eventually test and receive positive feedback for selecting the correct choice, but this is based entirely on a method of elimination. Joanne's response, at line 4, is to suggest that the choice of axes was "wrong". This and the graphs chosen to fit them. This does stimulate some analysis and she begins to interpret the graph when she observes, at line 4, "I suppose if it's distance, she's getting faster, isn't she?". However this is not developed and the group moves quickly on to the next episode with little further discussion. The group considers the flight of the birds in the next episode.

Group 4:Joanne, Caroline and Vicki
Episode 6. Birds (1.42.52)

1	J:	Never mind Vicki! (laughs)	As the long jump sequence begins to play.
2	J:	Are you telling me you're good at computers, Vicki? (laughs)	
3	V:	I pressed the er ...	
4	J:	Good on Nintendo! (laughs)	
5	V:	Yeh!	Vicki reselects.
6	J:	It goes like up, up and <u>down</u>.	Making a wave like motion in the air.
		I don't think it's that one.	Referring to graph 1.
7	C:	It's going down though, isn't it? It's either that one or the one before it.	Referring to 1or 2
8	C:	What's that? Distance? Try that.	Referring to choice of axes.
9	J:	Try that one.	
10	V:	Gosh that was good!	Positive feedback from the system.
11	J:	Well we got one right.	





This episode begins with Vicki, unintentionally, choosing the the wrong option from the menu. This results in the short exchange between Joanne and Vicki at the start. Joanne then takes her turn, at line 6, to begin to describe the motion, when she says that "It goes like up, up and down". She then adds that "I don't think it's that one". However there has been no agreement, or even discussion, on the focus of the task up to this point i.e. no progress on establishing the JPS. Caroline continues, at line 7, with an analysis of the motion when she says that "It's going down though" and adds an invitation at acceptance with "isn't it?". She adds further that "It's either that one or the one before it", despite the fact that there is no agreement on the focus of the problem. For the first time, at line 8, them and asks "What's that? Distance". The second axis is not discussed, which could be height or time. In spite of this, Caroline completes her utterance at line 8 with"Try that". Joanne takes her turn, at line 9, to agree by saying "Try that one". Vicki's response, at line 10, and Joanne's, at line 11, are both concerned with getting to the solution, or in Joanne's words "getting one right", in contrast to discussing a possible solution of the problem. In fact the problem was not agreed within the group at any stage of this episode and hence a JPS was not established.

The final episode which the group fully considers is the high jump. Once again the pattern of working is repeated. The group accepts the axes which come by default as they first view the sequence. At no stage is there any clarification of what the axes are, no discussion about the focus of the problem and hence no agreement on what this focus might be. There is a limited amount of discussion, related to the nature of the motion itself, between Joanne and Caroline, and very little contribution from Vicki. Eventually some guesswork leads to the selection of the correct solution and the group moves quickly on to the next episode. However there it is very nearly the end of the lesson and hence very little time is given to considering it.

10.0.0 DISCUSSION

10.1.0 INTRODUCTION

In this chapter the various strands of this study are drawn together and the empirical findings are summarised and related to the relevant aspects of the literature review. As a starting point it is appropriate to review the aim and objectives of the project. The aim has been to investigate the potential of collaborative learning using multimedia in the mathematics classroom. The initial objectives included the identification of the major claims of researchers arguing for a collaborative learning approach, by means of a review of relevant literature. A second objective was to review and evaluate current practice involving the use of Interactive Video and to determine the extent to which collaborative group work takes place. The development of classroom materials and approaches to facilitate collaborative group work formed the focus of a third objective. The final initial objective involved the evaluation of these materials and approaches with a view to giving future direction to further development of the project.

The further development of the project involved the continuing literature review in relation to collaborative learning and also to the use of multimedia. A second objective involved a focus upon the extent to which collaboration is evident in the effective use of multimedia. An investigation of the role for the teacher formed a third objective and the consideration of teaching and learning styles a fourth. The culmination of the project involved the evaluation and utilisation of the NCC *World of Number* multimedia package in the light of the initial aim and resulting objectives.

10.2.0 CYCLE 1: CLASSROOM TRIALS

A major issue to emerge from Cycle 1 classroom trials was the crucial importance of the role of the teacher. As participant observer, emphasis was placed on the preparatory organisation and production of the materials. These were of central importance in establishing the initial conditions in which collaboration could take place. However the issue, relating to the role of the teacher, arose not with regard to the design of the materials but delivery in the classroom. It was clear that assumptions had been made about the philosophy and teaching style of the classroom teacher which proved to be inaccurate, for reasons already outlined. The didactic and directive style of the teacher at the start of the project ran counter to the approach envisaged. However subsequent adaptation to the overall approach of the project ensured that the major aim of encouraging collaborative group work was achieved.

The overall response of the majority of pupils to group work was very positive. However it was not clear whether this increased level of motivation was due entirely to the nature of group work itself or whether it was also, partially, a response to the change from the normal dull classroom routine.

The use of the IV system was undoubtedly a further motivating factor. However there were problems associated with some groups in feeling that they did not have enough time using the system. This aspect was also apparent through the use of video recording which highlighted the relatively low levels of interaction, whilst working at the system. Although the materials were designed to introduce the pupils to a limited range of the software options available, the time needed to achieve this was clearly greater than that available during these trials. None of the pupils achieved sufficient competence with the system, in the time available, to fully explore the software and to begin to pose their own questions. The relative complexity of the software interface was certainly a barrier to progress and clearly there was a need for significantly more time at the system, in order for the pupils to become proficient in using the software.

10.3.0 INITIAL LITERATURE REVIEW

The initial literature review focussed on the work of the American research community and in particular the work of Johnson et al (1984). The starting point was to examine the relevance of research on co-operative learning and to consider the claims of its advocates. Early in this study it became evident that there are a number of clearly distinguishable research cultures in relation to collaborative group work. The major distinction that can be former, in general, emerging from the American research community and the latter from the British.

With regard to the level of effectiveness of co-operative group work, Johnson et al noted that co-operative learning seems to be enriched by heterogenity among group members. Bennett and Dunne also established that there was a relationship between the interaction in the group and pupils' understandings of the task. Neither of these claims was greatly illuminated by the experience of Cycle 1 classroom trials. However subsequent experience in this study resulted in these claims becoming more directly relevant and they will be returned to later in this chapter.

10.4.0 REVIEW OF INTERACTIVE VIDEO USE IN SCHOOLS

The review on the use Interactive Video in schools highlighted a number of important features for success, which were resonant with the experience of Cycle 1 classroom trials. One feature of a number of the case studies is the evident flexibility in teaching and learning styles. Evidence is provided of the use of the technology to promote whole-class discussion as an initial stimulus to classroom activity, with considerable evidence of small group work on the part of pupils subsequently. Some aspects of this were clearly novel as one of the case study teachers reported that although most of the school's teaching was based on group work and discussion, producing one piece of work from the group was new, and they had to learn to organise this. This lends further evidence to the findings of Yeomans (1983) and Bennett et al (1984) that what teachers commonly describe as group work is, in fact, most frequently simply an organisational arrangement involving pupils sitting together as a group with pupils working on individual tasks. Further evidence of group work is provided in the reports from two of the other case studies reported upon. The use of the system was seen to be a catalyst for collaborative group work, mainly as a result of the practical limitation of having only one work station available, as was the case in Cycle 1 classroom trials.

The importance of the role of the teacher attracted explicit comment from manager, discussion leader and also involved helping the groups to organise their tasks. This view of the role of the teacher is implicit in one of the further case studies and reinforced this aspect of the initial findings from Cycle 1 classroom trials.

A further issue to arise related to teachers' perceived need for considerable support. This seemed to relate not only to the use of the technology but also to the way in which this was incorporated into the ongoing scheme of work, through the organisation and preparation of classroom resources, in the form of video sequences and worksheets. Although unplanned, staff development was also a dimension to the experience of Cycle 1 classroom trials.

What also emerged clearly was the potential impact of Interactive Video for motivating the interest and enthusiasm of pupils. This seemed to be related to the power of the visual medium and was consistent the experience from Cycle 1 trials, even though this experience was restricted to the use of still as opposed to moving images.

10.5.0 LITERATURE REVIEW - CLAIMS FOR THE TECHNOLOGY

The review of the use of the technology in schools together with the experience as a Field Officer highlighted considerable confusion in terms of the expectations of users, which could be traced back to some of the claims made by proponents of its use. Some of these claims were in sharp contrast to my own starting point at the time of embarking on this project.

In particular there was a degree of media "hype" which in part was fuelled by the comments of some politicians e.g. Education (1987) and Training and Development (1988) and also by commentators themselves e.g. Wade (1988). An assumption of the unlimited power of the technology seems to underpin such views as does does an absolutist philosophy of education, based on a transmission model of the learning of facts and skills. A consequence of such a perspective is the belief that the teacher can be replaced by the machine.

essentially a clash of epistemologies which is not restricted to the application of technology in education. Brown (1993) expresses this phenomenon in the context of the "battle for control of the National Curriculum". She argues that, at its root, this is "a battle about what we mean by knowledge". She contrasts an elitist and absolutist philosophy as "perpetrated by right wing philosophers" with the empirical and genetic epistemology of educationists "derived from a corpus of work with pupils actively constructing their own knowledge".

10.6.0 LITERATURE REVIEW - MULTIMEDIA AND MATHEMATICS

The tension that became apparent during the course of this study was illustrated further through the literature review in relation to the use of multimedia and mathematics. Norris, Davis and Beattie (1990) draw attention to the "common worry", in relation to computer assisted learning in general, that authority is invested in the machine and also that the underlying pedagogy is didactic. They conclude that for the IVIS programme this was not a major issue in general terms as most of the developers had attempted to devolve control over the teaching and learning processes to the users and that, to varying degrees, they had succeeded. However they proceed to categorise the IVIS mathematics disc *School Disco* as a system of rules.

This analysis seems to be accepted by Kennett (1989), who argues that much IV use in training corresponds to computer aided instruction, in which the system transmits information and tests the learning. This view appears to be shared, in part at least, by Straker (1987) and also Atkins and Blissett (1989 and 1992).

In contrast the role of the teacher is emphasised by Norris, Davis and Beattie (1990) who report that the educators and educational researchers consistently identify the role of the classroom teacher as being the one factor central to the full development of the technology's use in schools. They also report that these findings were reflected in those of the IVIS project which demonstrated that the educational value of IV lies in area of role of the *Domesday* interactive video system in the mathematics classroom. He concludes that students using IV often work in small groups with a great deal of discussion in evidence. He also comments on the role of the teacher and describes a model of the classroom which does not see the teacher as simply a provider of knowledge but also as a classroom manager, student consultant and motivator. These findings are resonant with the experience of Cycle 1 classroom trials and also subsequent stages of this study.

10.7.0 CYCLE 2: CLASSROOM TRIALS

The experience in Cycle 2 classroom trials served to reinforce the view formed in Cycle 1 of the crucial importance of the role of the teacher. Having identified a strategy of targeting teachers who would be largely sympathetic to the aim of the project from the outset, this was successfully put into practice in this cycle. In fact, the enthusiasm and motivation generated by one of the class teachers did have the effect of deflecting the pupils from making as much use of the computer system as they might otherwise have done. This was also partially the result of unrealistic expectations of the extent of available material that was on the system, which may well have been related to the "media hype" referred to earlier.

As with Cycle 1, there was a very positive response from pupils to working in groups. The inclination of the pupils towards collaboration is particularly evident from their individual comments, which contain much evidence of pupils' willingness to negotiate and collaborate. The responses to using the Domesday system were generally positive with a larger proportion rating its use highly on Cycle 2 than on Cycle 1. The reasons given for enjoying the use of the system related to the nature of the information available and also to the visual aspects of the video disc. This seemed to be due to the fact that, in Cycle 2, the pupils in one of the classes in particular spent more time on, and therefore became more skilled with, the system. They also became more aware of the power of the system and the range of information that was available. Their comments not only reflect an interest in the nature of the information itself but also a positive the Domesday system which was cited by pupils was the relative ease of access to the information available on the disc.

However much of the activity by pupils in the lower ability group was not of a very mathematical nature. Several pupils in the class certainly developed their skills in using the system, but their enquiries were driven by their general interest in accessing information about particular topics such as football, popular music, drug addiction etc. Much of the information that was gathered was not necessarily presented in a mathematical way e.g. it was predominantly in the form of pictures or text.

Overall there was a positive response to the cross-curricular aspects of the project and it would seem that the influence of the teacher, especially with more able group, was a significant factor in generating this level of commitment and enthusiasm. In general the experience in Cycle 2 reinforced most of the initial findings from Cycle 1. There was more opportunity to observe pupils using the system to a greater extent than in Cycle 1. However this probably served to highlight the limitations of the system as much as it did to illuminate the potential.

The limitations on this occasion arose partially as a result of unrealistic assumptions being made about the contents of the disc on the part of the teacher of the more able group. The low level of mathematical activity with the less able group was really a result of the limitations of their ability to interact with the system at an appropriate level. This raised the issue of not only ensuring an adequate amount of time at the system but also of ensuring an appropriate match in terms of pupil ability. A further limitation of a technical nature was that the images which could be accessed were all in the form of stills, with no access to moving video.

10.8.0 LITERATURE REVIEW - DEVELOPING THEORETICAL PERSPECTIVE

As this study developed the continuing literature review focussed on collaborative learning in mathematics education and also in computer outcome of the review of the literature in each of these fields, together with the empirical data from this study, was an increasing awareness of the relevance of the theoretical perspective on teaching and learning provided by the work of Vygotsky (1962), which is also discussed in this section.

10.8.1 COLLABORATIVE LEARNING IN MATHEMATICS EDUCATION

The initial development of this study was significantly informed by the work of Eraut and Hoyles (1989) in relation to group work with computers. In their review of relevant research they identify three main sources for arguments for group interaction. The oldest of these is attributed to psychologists and educators who stress the role of language in learning, particularly spoken language (e.g. Vygotsky) and much of the British research can be seen to follow in this tradition. The second main source of argument for group interaction is identified as being related to oral language but giving primacy to the need for co-operative orientation among learners. This line is traced back to Deutsch (1949) and Bruner (1966) on which much of the American research is based. The third main source stems from the arguments of a group of Genevan developmental psychologists based upon a Piagetian theory of learning (e.g Doise and Mugny,1984; Perret-Clermont, 1980; and Bearison, Magzamen and Filardo, 1986).

The findings of this study are resonant with those of Hoyles (1985) in terms of the relevance of the Vygotskian idea of co-construction, rather than conflict, as a mechanism for cognitive change. The findings of Good, Mulryan and McCaslin (1992) also point in this same direction.

10.8.2 COLLABORATIVE LEARNING AND COMPUTERS

In the context of the use of computers, the findings of others researchers again proved to be resonant with those of this study. In relation to the importance of the role of the teacher the findings Hoyles and Sutherland (1987) and Riel (1989) reflect those of this study. My findings also echo those of Govier (1988) in relation to how microcomputer use in the classroom encourages cooperation and discussion. With regard to the work, the findings of Cummings (1991) and Johnson, Johnson and Stanne (1986) also support those of my study.

The findings reported by Hoyles, Healy and Pozzi (1994) and Pozzi, Hoyles and Healy (1992) are particularly resonant with those of this study in relation to their conclusions about their relevance to the debate on the social construction of mathematical knowledge and also to the Vygotskian idea of co-construction, rather than conflict, as a mechanism for cognitive change. Similarly the findings of Hoyles and Noss (1992) in relation to the importance of pedagogies which can be designed which "scaffold" students' sense making in mathematics echo those of my study.

10.8.3 THE DEVELOPING THEORETICAL PERSPECTIVE

The underlying philosophy which was brought to this study involved a commitment to an investigative approach consisting of collaboration, problem solving, practical work and discussion. Further significant aspects of this approach included a commitment to active learning, the flexible use of resources and the application of mathematics in real social and cultural contexts. This philosophy could be broadly described as constructivist. Major influences have been the radical constructivist philosophy of von Glaserfeld (1987) and also the social constructivist perspective as outlined by Jaworksi (1994).

As referred to earlier, one outcome of the ongoing literature review was an increasing awareness of the relevance of the theoretical perspective on teaching and learning provided by the work of Vygotsky (1962). As this awareness developed, this perspective became increasingly relevant to the empirical findings of this study.

In line with much of the research carried out in relation to collaborative learning in mathematics education (e.g. Good, Mulryan and McCaslin, 1992; Pozzi, Healy and Hoyles, 1993), the adequacy of a constructivist perspective when considering a social and communicative model of learning came increasingly under question. The questions raised by Lerman social constructivism helped to give direction to the development of an alternative view and in particular towards a socio-cultural view of learning based, in part at least, upon Vygotsky's cultural psychology. As the empirical findings of my study increasingly pointed in the direction of the development of such a perspective, so the lack of any clearly articulated theoretical perspective in relation to the literature on the use of multimedia and mathematics was highlighted.

In relation to the development of an alternative socio-cultural perspective the work of Forman and Cazden (1985) was found to be particularly relevant. They note that the exploration of Vygotskian perspectives for education immediately lead to questions about the role of the student peer group. They highlight Vygotsky's notion of internalisation, by which the means of social interaction, especially speech, are taken over by the child and internalised. This notion proved to be particularly relevant to the findings of my study. They also make reference to Bruner's (1985) notion of *scaffolding* which also proved to of relevance.

The work of Jones and Mercer in the context of computer education was also found to be particularly relevant in this context. Of particular significance to this study is their conclusion that Vygotsky's theory can accommodate the role of the teacher as an active communicative participant in learning, and not someone "who simply provides rich *learning environments* for children's own discoveries (a la Piaget) or reinforces appropriate behaviour if and when it occurs (in the behaviourist mode)". They argue for a model of the computer as a *medium* for the facilitation of communication between teacher and learner which was found to be particularly in keeping with the approach adopted in this study. Similarly the work of Cole and Griffin (1987) was found to be of relevance to my findings. In particular their notion of the *orchestrating* teacher was found to be especially relevant. Jones and Mercer are supported by Crook (1991) who argues that socio-cultural theory appears to offer the conceptual framework most capable of dealing with joint activity, and offers one of the strongest theoretical bases for the evaluation of computer-based educational for the evaluation of the resources and activities in Cycle 3.

10.9.0 CYCLE 3: EVALUATION OF *World of Number*

The issues arising from the process of evaluating the NCC package *World of Number* are summarised in this section.

The first issue to be encountered was the organisational complexity of the package, which arose both from the initial investigation of the package and also from teacher feedback and the literature review. However, in relation to this study, this did present a real, but not insurmountable, problem in the early stages.

The unit *Who Stole the Decimal Point?* proved to be the most accessible section of the discs. However there was considerable evidence of the danger highlighted by Goldstein (1990) of a preoccupation with a "solution" to the game, rather than with the mathematical problems themselves. Only close monitoring and teacher intervention ensured continuing progress and avoided frustration setting in on several occasions.

Uncertainty was apparent with regard to the mode of use of the materials. The teachers, in particular, expected that the designers would have addressed this issue. However it was soon clear, from this evaluation, that there would be a need to structure the use of the materials into the wider classroom context. It was also clear that there was a need to integrate its use with an ongoing scheme of work.

In the trial school, the predominant mode of use had clearly been whole class use, despite a recognition of the limitations due to screen size and level of pupil involvement in discussion. This limitation was also very apparent from the classroom observation, even with groups of between eight and ten.

The motivating aspects of the package which were particularly noted in the teacher interviews related to real world contexts and also to the use of peers by the members of the development team: Phillips, Pead and Gillespie (1995, to appear), who offer some observations on their own evaluation of the package.

The level of challenge in the materials is quite variable. From the interviews with staff, this was seen to offer an advantage, in terms of applicability to a wider range of pupils. However this did present particular problems for some students, when encountering a problem which was really beyond their capability, during the classroom observation. The need for guidance and support from the teacher was apparent in such cases.

The level of support for basic number work and low achievers was not seen to be a strength of the package by the teachers. Evidence from classroom observation supported this view and confirmed that *Decimal Point,* in particular, was concerned with problem solving skills and strategies rather than basic numeracy.

The issue of differing levels of interactivity had clearly been identified by the teachers. However this was not an immediate issue given the stage of development in using the package as a whole and the lack of any necessity to consider issues of cost effectiveness.

The major issue to emerge from the interviews with staff and which was reinforced during classroom observation relates to the role of the teacher, which is apparent on two levels. Firstly this can be seen to be crucial from the point of view of planning and structuring the activities into the context of the whole classroom and integrating these with an ongoing scheme of work. Secondly is the importance of the role in terms of guiding, supporting, intervening and, also at times, providing direction.

The unit to emerge with the richest potential for further development was *Running, Jumping and Flying*, given the fact that this unit was one of only two units in the package where there is interactivity, the software category is revelatory and there is some feedback built in for the user. The full power of the computer and moving video facilities are utilised in a way which could not be achieved by any other medium. Discussions had identified this as an area of interest on the part of the staff and some limited experimentation had already been undertaken in the classroom by one member of staff. An added advantage was the easy identification of an area of the mathematics curriculum for which the use of this unit would be relevant, although of little direct relevance to number.

For these reasons, it was decided to concentrate the next development stage of the study on exploring the potential of this aspect of the package. The intention was that, by this means, this study would come to represent an investigation of the full technological potential of multimedia in the mathematics classroom whilst, at the same time, focusing attention on the potential of collaborative learning in this context.

10.10.0 CYCLE 3: CLASSROOM TRIALS

Feedback from the post-trial interview with the Head of Department and class teacher confirmed the initial observations about the success of the activities in motivating the students. The plan to integrate the activities with the ongoing scheme of work was clearly perceived of as a success. Feedback from teachers emphasised that the real potential of the system could be realised in this way and that there had been real benefits to the Year 9 group using it.

In relation to small group work, it was felt that the group size of three had worked well. However there was also a wish to have been able to use the system with the whole group at certain points in time but also a recognition of the practical limitations. It was felt that there would be advantages, at certain points, to make use of the system in the context of whole group discussions to explore understanding.

In response to being asked to consider some of the more difficult graph options, such as distance against height, the importance of teacher intervention was stressed. It was felt that some of the differences between questioning "they could get to grips with it".

When asked to reflect upon what they had learned in using the system, one group of pupils emphasised how it had helped them to make sense of the situation. They indicated that they had not understood graphs at the start of the classroom project. However, they were able to comment on how they made sense of some of the more difficult graphs by the end, for example by close examination of the scale. Another group highlighted aspects of the video element as their major reason for enjoying using the system. They emphasised how the use of the system had helped them to make sense of graphs, seemingly for the first time. They also emphasised the advantages of joint effort and of sharing ideas when working in small groups.

The vast majority of the class had enjoyed the experience of working in groups. Reasons given included being able to discuss things, exchanging/ sharing ideas, helping each other and getting better results. The responses to using the multimedia system were even more positive, with almost everyone enjoying using it "very much" or "quite a lot". The single most significant reason, however, was related to the fact that it was novel. One pupil highlighted the aspect of choice as her reason. Another emphasised the learning gains from using the system, perceiving that using the computer helped her learn better.

In overall terms, the test results demonstrated an increased level of understanding between the pre-test (mean of mark 7.43/15) and the post-test (12.48/15). This reduced between the post-test and delayed post-test (to 11.65/15), but there was still a substantial increase between the pre-test and the delayed post-test in evidence. Comparisons at an individual level are more problematic but some reference will be made to this data at an individual level in the following sections.

Some of the issues to have arisen in Cycle 3 relate to the mode of use of the materials and also to the role of the teacher. In relation to the latter, these issues are apparent in two ways. On the one hand, there is the planning and the overall plan. On the other is the ongoing interactive role, involving guidance, support, intervention and, at times, direction. These issues were apparent from the early evaluative stage of this cycle and were reinforced during the developmental stage.

Of particular resonance are the ideas related to Vygotsky's "zone of proximal development" and Bruner's associated idea in relation to the critical function of the teacher in "scaffolding" the learning task. An illustration of this resonance is provided by the class teacher's response to being asked to consider some of the more difficult graph options:

> *Well I think without teacher intervention, I don't think they appreciated the difference - the subtle differences between the two, between vertical height and distance, and vertical and time, for example, and so it certainly needed some teacher intervention to draw that out but I think ... the subtle differences are quite difficult to appreciate, just on their own I don't think they would have thought about them. But once you started to question them they could get to grips with it - the fact that the distance one stopped at the end whilst the time one went on - they could see that (by running the video).*

The multimedia system, in this case, is fulfilling a unique function which would not be easy to replicate in any other way. Some of the feedback from the pupils themselves also seemed to emphasise the way in which the system supported their own sense making of the situation.

10.11.0 CYCLE 3: MULTIMEDIA-BASED ACTIVITIES

The video tape transcripts from Cycle 3 classroom trials record the work of four of the groups working on the multimedia-based activities. For three of the groups, almost their entire time working on these activities was recorded. This aspect of the classroom activities really provides the focus for this study as a whole and the video tape transcripts represent the culmination of the associated data collection.

The main aims of this activity were to promote discussion and require time for reflection which was consistent with one of the preliminary findings of the NCET evaluation, as reported by Hughes (1994), of the need for "reflective moments". The activity was structured in such a way as to encourage the pupils to select and view a video sequence, think about the distance-time graph, sketch the graph, compare each others' graphs and to choose a graph to fit their ideas. They were further encouraged to explain to each other why a particular graph does or does not fit, test out their choice on the system for feedback and then to repeat the process with a different choice of axes.

This process can be summarised as a **cycle of observation, reflection, recording, discussion and feedback**, as illustrated in Figure 11.

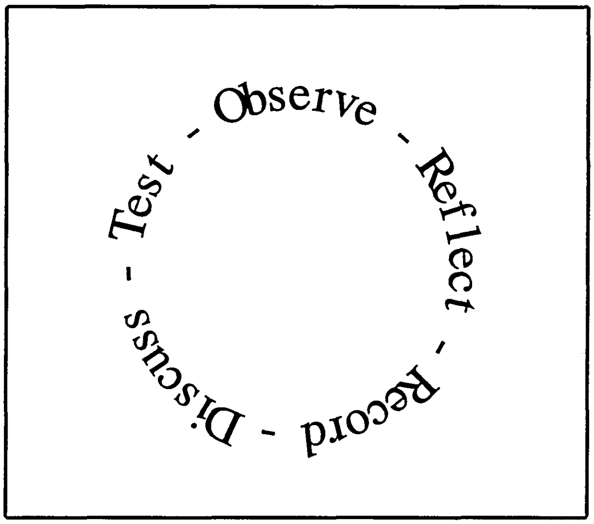


Figure 11

10.12.0 CYCLE 3: ANALYSIS OF THE VIDEO TAPE TRANSCRIPTS

In adopting a detailed and qualitative approach to the analysis of the discourse in Cycle 3 of this study, the methodology of Mercer (1991) and also Edwards and Mercer (1987), was found to be particularly relevant to this study. The interpretive framework was adapted from that of Teasley and Rochelle (1993).

First impressions, from the initial viewing of the video recording of the multimedia-based small group work, reinforced those formed during the course of the classroom trials of collaboration and some rich interaction.

collaboration and some quite superficial interaction. In the first part of this section the pattern of interaction of each the three groups is compared and contrasted.

Another major issue to emerge from this analysis relates to the way in which the development of Neil's understanding is highlighted. By examining the development of Neil's misconceptions, which is evident from the discourse resulting from peer interaction in particular, this analysis serves to illuminate Vygotsky's notion of the function of *egocentric* speech. This section is considered to be of particular significance because of the resonance it provides with one of the ideas which is central to Vygotsky's theoretical perspective on the social construction of knowledge.

10.12.1 CONTRASTING PATTERNS OF GROUP INTERACTION

10.12.1.1 LAURA, CHANTEL AND CLAIRE

Laura, Chantel and Claire provide clear evidence of collaborative interaction and joint problem solving activity. However the first episode to be considered in chapter 9 was in fact the group's fifth episode. Episodes 1 to 4 are fully detailed in Appendix 2(ii). In Episode 1, the group is clearly preoccupied with simply getting to the solution by a process of guesswork and elimination. This leads to an early intervention by the teacher-researcher in order to clarify the task in the following episode. This process is continued in episodes 3 and 4 by a significant level of involvement by the teacher-researcher. Once the whole group seemed to have a clear understanding of the nature of the task and of the software control interface, then the teacher-researcher withdrew.

In the first episode of peer interaction to be considered, Episode 5: Cheetah, there is clear evidence that a JPS has been established, from the initial stage of agreeing on the problem itself to the subsequent discussion of it and then to its eventual solution. Claire's participation, however, is minimal up the culmination of the activity. Up to that point, her contributions related to the choice of problem and to the clarification of her own understanding, rather than to the solution of the problem itself. In the second part of this episode, contribution at all.

A particular feature which soon emerged from the analysis was the pattern of Chantel's utterances. Chantel is instrumental in giving a lead to the collaboration throughout the episode concerning the cheetah, by the way in which she combines her assertions with a question inviting acceptance or repair. Over the course of this episode Chantel asks most of the questions which are posed, of which five are of the form "wasn't he"/"won't he" etc and are linked to a preceding statement. In using this technique, Chantel not only gives a lead to the interaction in the group but also facilitates the responses of the others, with her invitation for acceptance or repair. In this respect Chantel's role is resonant with Vygotsky's notion of "a more capable peer" in relation to the zone of proximal development.

In the following episode, involving the pole vault, Claire's role is distinctly different. Early in the episode, Claire contributes to the solution of the problem, using the technique previously used by Chantel to link an assertion with a follow-up question inviting an acceptance or repair. She outlines what she thinks the graph should look like and invites acceptance or repair, when she says that "it would go up, wouldn't it?". Claire continues to give a lead to the group and attempts to repair the shared understanding of the problem when she remarks that "he's still travelling when he pole vaults". This utterance is in response to Laura's forceful rejection of Chantel's earlier suggestion. The interaction continues when Laura accepts Claire's suggestion and begins a further statement, which is subsequently completed by Claire. This is the first example of what Teasley and Rochelle (1993) describe as a collaborative completion.

The episode continues with Claire feeling sure enough to make a suggestion. However this is rejected forcefully by Laura who offers an alternative. Once again Claire makes a further suggestion which is in fact correct. However Laura is again quite forceful in asking her to wait and in suggesting that they try another option. This results in Claire becoming uncertain and suggesting that it could be another graph. This is

However without waiting for her to complete the sentence, Laura points to the section on the correct graph, which shows him "going across". Chantel, who has said little since making her initial suggestion, but who has evidently listened carefully to the others, now makes a well timed assertion which is immediately accepted by Laura with her suggestion to test it, followed by the resulting positive feedback from the system.

Chantel seemed to have decided, at quite an early stage in this episode, which was the correct graph. However, Laura appeared to spend the early period sketching her own ideas and subsequently seemed to need to evaluate all the options available on the system. Chantel certainly stood back whilst Laura went through this process. Meanwhile Claire assumed a much more leading role but seemed to lose some of her initial confidence through the interaction with Laura, who was quite forceful in her rejection of some of Claire's later suggestions. Up to the point where Claire seemed to lose her confidence, her role was similar to that of Chantel's in the previous episode i.e. that of the more capable peer. She also made use of the strategy of inviting acceptance or repair, previously used effectively by Chantel. This change of role is resonant with Forman and Cazden's (1985) notion of "complementary problem-solving roles".

The work of this group also provides several examples of the use of language combined with gesture in response to what is being observed on the computer screen. For example, in episode 6: The Hurdles, Chantel, uses both language and gesture, when she explains that he is "going along the hurdles" and, at the same time, making a horizontal wave motion in the air. She also invites acceptance, in her characteristic way by means of "isn't he?", and adds that "He'll be going at constant speed along the hurdles". Here she makes a link between constant speed and the notion of "going along", which seems to convince Laura. Chantel also uses the sketch of her graph to support what she is saying in a later part of this same episode. This was a strategy which was used by all the group on several occasions throughout their period of time at the system.

In the following section, Episode 9: Long jump, Claire then begins to make a statement which Chantel repeats and completes. Claire then begins a question, but is again interrupted by Chantel, who who uses both language and gestures to show that "it goes at constant speed". She later continues her explanation of the graph, when she states that "then it stops like that", with reference to her own sketch showing the section of the graph as it flattens out. Chantel then recognises the necessary adjustments to her own sketch, from viewing the available graph option, and seems sure in her selection which is confirmed by feedback from the system. At this stage Chantel is totally engaged with the problem and appears to carry the other group members with her, as she maps out the graph with her hand and points to the final section of the graph, which displays the period after the jumper has landed.

These examples are resonant with the claims for the role of the computer in supporting collaborative learning, made by Teasley and Rochelle. They argue that participants in collaborative activity are not wholly dependent on language to maintain shared understanding. They see a major role for the computer in supporting collaborative learning by providing a context for the production of action and gesture, which can serve both as presentations and acceptances. Thus the simultaneous production of matching language and action by separate partners can provide opportunities for acceptances of new ideas and also for repairs. The system also fulfils the important function of confirming choices and bringing episodes to a successful completion. There is further resonance with the arguments of Jones and Mercer (1993) in relation to the the role of the computer in the learning process. They argue that a communicative approach might place less emphasis on the relationship an individual learner has with the computer and more on the computer as a medium for the facilitation of communication. This argument is put, mainly from the point of view of the teacher-pupil relationship by Jones and Mercer. However the results of this study also highlight the significance of such a role for the computer/ multimedia system in acting as a medium for communication between peers.

10.12.1.2 PHILIP, NEIL AND JONATHAN

Philip, Neil and Jonathan formed the second group to be considered. Early in this first episode Philip initiates the discussion by beginning to narrate his analysis of the actual motion. This gives rise to another example of a collaborative completion. Philip's initial action also prompts Neil to narrate his analysis which has the effect of cutting short Philip's initial statement. However Philip interjects with a statement in the form of a collaborative completion of Neil's utterance.

Neil quickly asserts that "That'll be what it's like", as a result of studying the graph option on the screen. However he provides no explanation, nor has the problem been previously defined and agreed i.e. it is not clear whether the group is considering distance against time or speed against time etc. The initial exchange between Philip and Neil centred on the speed of the cheetah and from this they seem to have developed a shared understanding that the problem is about the graph of speed against time. However Jonathan's utterance of "What?" seems to suggest the need for some shared understanding of the problem or of some definition of what "it" (the problem) actually is on his part.

In this episode, there is evidence of collaboration, with a collaborative completion occurring between Philip and Neil at the start. However a JPS is not established between all members of the group. Jonathan is clearly uncertain about the nature of the problem itself and his utterances are aimed at seeking clarification. In relation to the JPS, this clarification is not achieved for Jonathan up to the end point of this section of the episode.

Subsequent intervention by the teacher-researcher revealed that the group did not have a clear understanding of the nature of the software interface. In particular there was a need to clarify the process for selecting a different choice of axes. There was also a need to clarify the process for testing the chosen option to gain feedback from the system, which the group seemed to forgotten how to put into effect.

In the following episode, about the election, Jonathan uses language and gesture to describe the graph "going up", by sketching the graph in mid air. From Neil's utterances it would appear that he is very confused in his thinking, which elicits further intervention from the teacher-researcher in an attempt to clarify matters. The nature of Neil's utterances is treated separately in the following section of this chapter.

The initial exchanges in the following episode, about the high jump, are concerned with the social relationships of individuals within the group and issues of choice and control, rather than the establishment of a JPS. Once again Philip initiates the discussion in relation to establishing a JPS, with his question to clarify the focus. Philip also initiates discussion related to an analysis of the motion. Neil displays confusion which leads to Jonathan taking his turn, with an attempt at repair of the shared understanding, when he uses language and gesture to describe the motion.

Later in the episode Philip initiates discussion about the problem itself by reading the graph in terms of the actual motion. He begins by stating that "She runs along". This prompts Jonathan to intervene and continue that "She runs and she goes like that". At the same time Jonathan makes a wave motion in the air to signify the up and down motion of her initial run-up. Before Jonathan has paused for breath, Philip completes the train of thought by stating that "She jumps. She falls and then stands up again". Once again he invites acceptance, by adding "doesn't she?" During this interaction there is a high level of excitement and, although it is not distributed over a single sentence, the interaction between Jonathan and Philip as a whole could be seen as a collaborative completion of a particular line of thought.

Philip's role in this group is similar to that of Chantel in the first group, in the way that he fulfils the role of more capable peer. There are also similarities between the two groups by the way in which individuals use coordinated language and gesture, supported by the computer as a medium for communication. Jonathan, in particular, makes extensive use of this strategy, when seeking to explain his thinking to the other members of the group.

... between the patterns of interaction in these first two groups emerges in the following section of the high jump episode. In this episode there is an example of conflict and challenge, which is initiated by Neil with his question "Why does she do a jump?". This seems to be interpreted by Jonathan as doubting the validity of part of his previous analysis. His response is to "Play it!" and Philip takes his turn to be even more emphatic in his demand to "Test! Test!" and to "See". Jonathan continues the exhortation with his command to Neil to "Watch!". Neil's good humoured response, "Let's have a look at this ...", seems to suggest a willingness to reconsider. He appears to make a concession to the others, but clearly Philip is not satisfied and again exhorts Neil to "Look". Neil's response of "Let's see her do her little jump!" is said scathingly and it appears that Neil is not at all convinced. This challenge sparks off a quite intense and excited exchange, beginning with Philip's commentary on the video of the motion as it plays. He observes that "She starts off running" and Neil is exhorted to "Look there!". Neil seems to begin to retreat, but is interrupted by Philip's continuing commentary. Philip makes the crucial observation, which fits with his interpretation of the graph, that she "Jumps up". Jonathan and Philip both respond to the positive feedback from the computer triumphantly. This is received with good humour, in the spirit that seemed to be intended. This example provides evidence of the effect of conflict, rather than collaboration, on the level of social interaction. Although there is evidence of a shared understanding and collaboration between Philip and Jonathan, it seems to be the conflict with Neil which is the trigger for the quite intense period of constructive interaction which takes place. There is resonance, in this example, with the findings of Johnson et al (1984) that active participation in co-operative learning groups produces conflicts among ideas, opinions, conclusions, theories and information of members and that this can result in increased motivation.

Another distinct difference between the two groups is the degree of confusion displayed by Neil throughout these episodes. Neil seems to experience the greatest difficulty of all the participants in these two groups and appears to be the least capable, in terms of achieving mathematical understanding. This is supported by the evidence of the test results, with Neil's marks being consistently the lowest, on each of the three tests. This, however, is the extent to which these results are considered to provide a reliable basis for individual comparisons.

	Pre-test	Post-test	Delayed post-test
Group 1:			
Laura	12	abs	8
Chantel	12	15	14
Claire	10	14	15
Group 3:			
Philip	8	15	8
Neil	5	8	4
Jonathan	13	11	13

The level of interaction in Neil's group, in particular, does provide evidence in support of the claim, by Johnson et al (1984), that co-operative learning seems to be enriched by heterogenity among group members and that the exchange of ideas among students from a variety of ability levels enriches their learning experiences. This claim is also supported by considering the other end of the spectrum and the way in which Chantel and Philip emerged as "more capable peers" in each group respectively. This phenomenon is resonant with the findings of Hoyles, Healy and Pozzi (1994) that *navigated* interactions led to the greatest learning benefits. The nature of Neil's difficulties will be returned to later in this chapter, as a particular individual case study.

10.12.1.3 JOANNE, CAROLINE AND VICKI

The third group to be considered is made up of Joanne, Caroline and Vicki. During their first episode they did not appear to be fully proficient in the control of the software. This led to the group requesting the help of the student teacher who was observing the activity. Although the student teacher confirmed that the focus of the problem was the graph of distance against time, this was arbitrarily changed to one of height against time. This probably reflected a lack of confidence in controlling the software on the part of the student teacher. Nevertheless, an attempt by Vicki to intervene with a question was blocked and a further observation by Joanne the motion itself, with which the pupils are able to agree. However this is not related to the chosen variables in any way. The analysis is followed by the statement "So try that", suggesting a line of reasoning although this had not been articulated. The response to the feedback from the computer was simply to "Try that one then", without any further analysis or reasoning being given. This intervention was not effective and the pupils were left with no greater understanding of the problem or greater capability in controlling the software. If anything, a tendency towards a preoccupation with the solution had been reinforced by the episode.

Early in the following episode Joanne asserts that "It's not that one" and subsequently, that "It's that one. It's that one". However the nature of "it" has not been discussed or previously agreed by the group i.e. the Joint Problem Space has not been established nor has any discussion towards its establishment taken place. Caroline begins to try to clarify the nature of the problem with her question "Is it distance against time?". Joanne seems to assume that it is but Vicki points out that it is speed against time. Caroline seems to suggest changing the axes to distance against time but none of the group appears to know how to change the axes. Joanne seems disheartened and confused when she asks "What are we doing? Just trying? Just trying?" and seems to answer herself with "Test".

Given the failure to establish a JPS and also to fully control the software, it would appear that Joanne is ready to settle for just getting to the correct solution. This seems to set the pattern of interaction for the rest of the work of this group. Vicki's contribution to this episode relates to a technical option with the software, rather than being concerned about the problem itself, which in fact is typical of the nature of most of her limited interaction. Caroline's response implies acceptance but seems to suggest that it is of minor significance. Joanne, however, protests that "You can't have that ... we haven't got the graph on now". In fact the graph was being overlayed on to the full screen motion, but none of the group seemed to be aware of this. It was also the case that the axes were set to height against time and, by chance, they had matched up the correct graph although they how there was no discussion about the problem itself and also how there had been no progress in establishing, or even agreeing on the focus for, a JPS.

In this next episode about the aeroplane landing, Caroline begins by clarifying the focus of the task. Having confirmed the focus of the task, Caroline then seeks to consider the available options. She immediately answers herself, by dismissing graph 2, but does not provide any reason for her rejection. Caroline seems to begin to conjecture, which prompts Joanne to interrupt by repeating her words and completing her sentence. Joanne then asks "Is it that one?", up to which point there has been no discussion of the motion or of the problem itself. Caroline's attempt to analyse the motion can be seen as the start of the negotiation of a JPS. She remarks that "It comes down gradually" and invites acceptance by adding "doesn't it?". Joanne's question of "Is it going down or is it on the flat?" allows Caroline to respond by explaining that "It's the plane landing". This short exchange between Caroline and Joanne is, however, the only discussion which takes place about the problem itself. Caroline proceeds to suggest "Try that!" and Joanne echoes this with "Test it!".

A particular feature of the interaction in this group is the minimal level of involvement of Vicki, although she has control of the mouse throughout the entire time that the group was being recorded. In this last episode, her only contribution was to confirm the chosen graph option on the system. Another feature is the minimal level of discussion about the problem itself. For example, most of the discussion centres, initially, on defining the focus of the task and then on simply deciding which graph fits. There is no evidence of individual sketching of graphs or of any prior reflection. Another significant feature is the fact that, on each occasion, the group only considers the axes which come up by default each time. So, for example, they did not consider the options of height or distance against time in relation to the aeroplane landing in this case.

In the next episode, concerning the cheetah, the overall level of interaction clarifying the focus of the task. Joanne asks "Is it speed?", whilst looking at the graph option. She seems to be really asking the question "Is this graph the correct option for speed against time?". She seems to decide that it is correct and Caroline's response is to "Try that". Vicki's question, once again, simply seeks confirmation of the choice, in order to execute this on the system.

In the next episode, Episode 5: Long Jump, Caroline asks "Shall we draw it?", to which Joanne responds "Oh no we'll draw it afterwards. Test it. Incorrect". They eventually test and receive positive feedback for selecting the correct choice, but this is based entirely on a method of elimination. Joanne's response is to suggest that the choice of axes was "wrong". This in fact reversed the problem, in that the axes were decided upon at the start and the graphs chosen to fit them. This does stimulate some analysis and she begins to interpret the graph when she observes "I suppose if it's distance, she's getting faster, isn't she?". However this is not developed and the group moves quickly on to the next episode with little further discussion.

In the next episode, about the birds, Joanne begins to describe the motion, when she says that "It goes like up, up and down". She then adds that "I don't think it's that one". However there has been no agreement, or even discussion, on the focus of the task up to this point i.e. no progress on establishing the JPS. Caroline continues, with an analysis of the motion when she says that "It's going down though" and adds an invitation at acceptance with "isn't it?". She adds further that "It's either that one or the one before it", despite the fact that there is no agreement on the focus of the problem. Caroline does eventually refer to the axes when she points to them and asks "What's that? Distance". The second axis is not discussed, which could be height or time. In spite of this, Caroline completes her utterance with"Try that". Joanne takes her turn to agree by saying "Try that one". Both Vicki's response and Joanne's are concerned with getting to the solution, or in Joanne's words "getting one right", in contrast to a response to successfully solving the problem. In fact the problem was not agreed within the group at any stage of this episode and hence a JPS was not established.

In the next episode the group considers the high jump. Once again the pattern of working is repeated. The group accepts the axes which come by default as they first view the sequence. At no stage is there any clarification of what the axes are, no discussion about the focus of the problem and hence no agreement on what this focus might be. There is a limited amount of discussion, related to the nature of the motion itself, between Joanne and Caroline, and very little contribution from Vicki. Finally some guesswork leads to the selection of the correct solution.

The level of interaction within this group was very much in contrast to that of the other two groups to be considered. A significant feature of much of the work of the group is the failure to establish a JPS, which is combined with an inability to fully control the software. A superficial observation would have suggested that they were interacting with each other and with the system quite constructively, and also that they were receiving positive feedback from the system. However this close analysis does illuminate how misleading this impression would in fact be. This finding supports the observations made by Atkins and Blissett (1989) in their study of the role of pupil discussion, which they note varied from a trivial and superficial conversation about the problem to real engagement with its constraints and possibilities. They argue that, although discussion takes place, and that this looks like evidence of interaction it does not of itself guarantee effective learning. With regard to the interaction of this group, it was more often the case that there was no discussion about the problem and no progress in establishing, or even agreeing on the focus for, a JPS.

The level of discussion was rarely about the problem itself. For example, much of the most constructive discussion merely centred on defining the focus of the task and then on simply deciding which graph fitted, by a mixture of luck and guesswork, reflecting the dangers predicted by Hughes (1994) and Goldstein (1990) of a concern with the solution rather than the problem. There was no evidence of individual sketching of graphs or of any prior reflection. This was one of the central aims of the design of the multimedia-based activity, which was consistent with one of the preliminary findings of the NCET evaluation, as reported by Hughes (1994), of the need for reflective moments and also with the need for reflection on the mathematical features of the problem itself, as argued by Hoyles and Noss (1992).

In fact, Caroline did suggest that they should sketch the graphs in Episode 5. However, her suggestion was dismissed by Joanne and she did not press her suggestion further. The relatively low level of interaction in this group is also consistent with the claim made by Bennett and Dunne (1989) that there was a relationship between interaction in the group and pupils' understandings of the task.

Another distinct difference, between this group and the previous two, was the way in which a "more capable peer" failed to emerge. Caroline seemed to show the potential on a number of occasions, when she sought to clarify the task itself and also when she made her suggestion about sketching the graphs. However the force of Joanne's personality seemed to dominate the working of the group and from the start, when there was some evidence of her becoming disheartened and confused, Joanne seemed to be more concerned with the solution rather than the problem. A further particular feature of the interaction in this group was the minimal level of involvement of Vicki and also the fact that she was in control of the mouse throughout. Subsequent classroom observation and discussion with the class teacher suggested that Vicki was generally not well motivated and participated at a minimal level, if at all.

On the surface this group had seemed to be collaborating and interacting constructively. The fact that this was not the case would seem to reinforce the importance of the role of a teacher in closely monitoring the quality of the process.

SPEECH BY CONSIDERING PUPIL MISCONCEPTIONS

This section focuses on Neil's utterances in particular and considers how these might illustrate the development of his thinking. The following is drawn from Episode 2 of Group 3, which is the interaction concerning the cheetah. It begins with Jonathan and Neil's responses to the question posed, about what the graph of distance against time might look like:

> *N: Distance is ... It goes up - the distance doesn't it? Well like along. Time.*
> *BH: What's happening to the distance?*
> *P: It's getting greater.*
> *N: It's going up. Higher.*

Neil appears to be confused in his thinking, when he asserts that "It goes up - the distance", seeking acceptance or confirmation with the question "doesn't it?". He continues with the utterances "Well like along" and "Time". From these it would appear that Neil is very confused in his thinking. This elicits an attempt to clarify matters, with the question "What's happening to the distance?". Philip replies correctly that "It's getting greater". However Neil's response suggests a confusion between the graph itself, which is indeed *going up* the page, and the actual distance which is *increasing*. A feature of Neil's thinking is this lack of distinction between the motion itself and its abstract graphical representation.

In a later episode, Episode 4, showing the aeroplane landing, this aspect of Neil's thinking is again evident. The axes are initially set on height against time.

> *N: Speed against time that.*
> *P: Yes but no. We've got to choose which height against time is the right one.*
> *J: Let's have a look.*
> *N: Yah!*
> *Oh! How come it does all the wavy lines?*
> *It goes straight down.*
> *It doesn't go up and down does it?*
> *J: Well change it! Have a look ...*

N: No! That's not it!
J: That's not it!
N: It's taking off that, isn't it?

Philip's response to Neil's initial statement appears to be contradictory. He replies "Yes but no". By this he may have been indicating that, "yes", the <u>graph</u> showing is the correct choice to fit the speed against time axes but that, "no", it is not addressing the current problem which is "to choose which height against time is the right one." In doing so, Philip is attempting to establish the JPS.

Neil's response to the video sequence would seem to be based upon an expectation of a smooth line, which probably reflects the more simple models from his past experience. However Philip observes that the nose of the aeroplane "goes up" on landing. The final comment in this section from Neil, displays evident confusion between what he interprets from the graph and what he observes by watching the video sequence, which is clearly of the plane landing. The fact that the graph is rising from left to right suggests to Neil that this is the flight path of the aeroplane taking off.

It would seem that Neil's misconception is related to the fact that he is describing the picture that he sees on the page i.e. "It (*the line*) is going up (*the page*). Higher (*up the page*)". The inability to distinguish, between the abstract representation of the motion pictorially and the motion itself, would explain why Neil interpreted this graph as showing the aeroplane taking off.

Neil's difficulties appear to stem from his use of speech and in particular from the lack of distinction he makes between the situation that he is describing, and its abstract representation in the form of the graph. For example, this can be highlighted in the following utterances of Neil, taken from the interaction above:

N: Yah!
Oh! How come <u>it</u> does all the wavy lines?
<u>It</u> goes straight down.
<u>It</u> doesn't go up and down does it?

When Neil refers to "it" doing "all the wavy lines", he would appear to be referring to the graph, though he does not make this clear. However, in the subsequent utterances, he seems to refer to the aeroplane when he talks about "it" going "straight down" in contrast to it going "up and down". Later in the same episode the group considers distance against time.

N: Distance is going down?
No! How could it be going down - distance?
Oh, it's just landed.
But its time's going up!
|P: What?
|J: The distance? It can't ... can't ...
|N: ... go down. It just goes up.
|P: I know it can't.
|N: So, why does it look like that then?

Neil's stream of utterances at the start form a narration of his current thinking, which once again appears to be very confused. He seeks to interpret the graph in terms of the possible motion of the aeroplane. His first utterance relates to a perception of the distance *going down* rather than *decreasing*.

Once again, Neil fails to make a clear distinction between the situation and its abstract representation in the form of the graph. In the first utterance from this interaction, he uses "it" to refer to at least two aspects:

> *Distance is going down?*
> *No! How could it be going down - distance?*
> *Oh, it's just landed.*
> *But its time's going up!*

Firstly he uses "it" to refer to the distance, then in the following utterance refers to the aeroplane and finally talks about "its" time going up. He seems to dismiss this as a possibility but then refers to the fact that the plane has the distance *going down* might be linked with the plane landing. This might suggest a confusion between the height and the distance (*going down*). However the notion of going down in this case would appear to have been transferred from (going down) the page to (going down) in mid-air. The evident inability to distinguish between the abstract graphical representation and the motion itself would be consistent with his previous thinking. He concludes with the utterance "But its time's going up!" which seems to emphasise his state of confusion.

In response, Philip simply asks "What?", and Jonathan attempts to repair the understanding, by beginning to suggest that the distance can't decrease. However Neil does not allow him to finish and completes his sentence for him with "... go down. It just goes up." Although this completion is distributed over a single sentence, there is evident conflict within the group in terms of their shared understanding. Although Jonathan does not protest, it is not clear that he would have used the same words as Neil, and Neil's use of language seems to be a major contributory factor towards his confusion. In fact Philip intervenes and asserts that "I know it can't (go down)" which elicits the question from Neil "So, why does it look like that then?".

Neil's use of language throughout is resonant with the function of speech as outlined by Vygotsky (1962). According to Vygotsky's theory, which was based upon a critique of that of Piaget, speech can be considered to have two particular forms which he describes as egocentric and communicative respectively. The notion of communicative speech is based upon Piaget's idea of socialised speech. However Vygotsky proposes that both egocentric and communicative speech are social, but that it is their functions which differ. The function of communicative speech, as implied in its description, is for the purpose of communication with others. On the other hand, the function of egocentric speech is as an instrument of thought itself. He develops his view of the function of egocentric speech, by arguing that all silent thinking is "nothing but egocentric speech".

description of egocentric speech. From observations based on his own experiments, Vygotsky notes that children resort to egocentric speech when faced with difficult situations. From these observations, he concludes that egocentric speech and silent reflection can be functionally equivalent. He argues further that egocentric speech is the genetic link in the transition between vocal and inner speech, and that it is this transitional role that lends it such great theoretical interest. He proceeds to highlight how the conception of speech development "differs profoundly" in accordance with the interpretation given to the role of egocentric speech. The resulting picture of the development of a child's speech and thought is thus from the social, to the egocentric and finally to inner speech. Thus the direction of the development of thinking is not from the individual to the social (as argued by Piaget), but from the social to the individual.

In supporting his argument, Vygotsky describes "an accident" which occurred during the course of one of his experiments, which he suggests provides a good illustration of one way in which egocentric speech may alter the course of an activity. He recounts a young child who was drawing a "streetcar" when the point of his pencil broke. Nevertheless, he tried to complete the circle representing the wheel by pressing down on the pencil very hard. However nothing showed and the child muttered to himself, "It's broken." He then put aside the pencil, selected a paint brush instead and proceeded to draw a broken streetcar after an accident, continuing to talk to himself from time to time about the change in his picture. Vygotsky uses this incident of the child's accidentally provoked egocentric utterance as an example to show how it "so manifestly affected his activity that it is impossible to mistake it for a mere by-product, an accompaniment not interfering with melody". Vygotsky develops his argument by describing how, from his observations, egocentric speech at first marked the end result or a turning point in an activity, then was gradually shifted towards the middle and finally to the beginning of the activity, taking on a directing, planning function and raising the child's acts to the level of purposeful behaviour. He compares this process to the well-known developmental sequence in the naming of drawings. A small child draws first, then decides when it is partially completed. Finally she decides beforehand what she will draw.

Neil's egocentric utterances are provoked in response to the examples of motion and also to the possible graphical representations of these which he sees on screen. From episode 2, it can be seen that Neil describes the distance as going up, when it is in fact increasing. As indicated earlier, the graph of distance against time could be described, quite reasonably, as going up the page. However, Neil does not distinguish between his descriptions the motion itself and those of its abstract graphical representation. In the later episode of the aeroplane landing, he is now faced with a situation which involves vertical motion, for which the use of the term going down would be appropriate and for which, in more general situations, it would be quite appropriate to describe an aeroplane taking off as going up. In a similar way to Vygotsky's example of the streetcar, Neil's interpretation seems to be affected by his previous egocentric utterances, when on viewing the graph which shows a diagonal line, rising from left to right, he responds by saying "It's taking off that, isn't it?".

Neil's confusion is exacerbated by the fact that the graph which he sees on screen is not a simplified idealised version but a realistic representation of the downward motion of the nose of the aircraft, which is not uniformly smooth. With apparent reference to the graph, he asks, "How come it does all the wavy lines?" and adds, with seeming reference to the aeroplane, that "It goes straight down. It doesn't go up and down does it?" Subsequently he describes the distance as "going down" and his thinking would appear to have been affected by his previous egocentric utterances with regard to the aeroplane. The notion of the "distance going down" now seems to be transferred from the abstract graphical representation to the situation itself, and Neil exclaims, in what appears to be a series of entirely egocentric utterances:

> *No! How could it be going down - distance?*
> *Oh, it's just landed.*
> *But its time's going up!*

with "... go down. It just goes up." This statement would be consistent with an interpretation of the graph going up the page, to which the notion, at this point, appears to have returned to.

The interaction continues as follows, with Philip's response to Neil's question, "So why does ot look like that then?":

> *Cos it starts from the bottom and goes up.*

In giving his response, it is clear that Philip is referring to the graph but using Neil's terminology i.e. "it ... goes up". Neil subsequently confirms that "It is right", as positive feedback is obtained from the system. His final utterances concern an explanation for the graph being "right". The reason he gives is:

> *Because distance goes up and so does the time, at the same time.*

Neil seems to be satisfied and this utterance would be consistent with a description of the abstract representation of the motion, based on the interpretation of the line going up the page, as opposed to being a description of the motion itself.

Neil's confusion is apparent once again, however, on the delayed post-test, when he responds to the graph shown in Figure 12, as follows:

Example from the delayed post-test

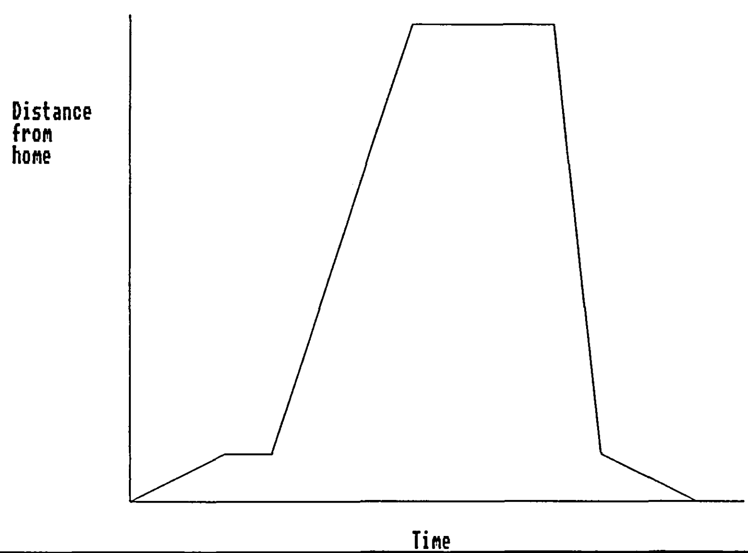


Figure 12

runway it pauses for a little while and hovers forward into the air but stops for a while then it comes back down again.

On this occasion it would appear that the notion of height, in terms of the motion itself, has become associated with the abstract graphical representation, which in turn seems to override the fact that the question concerns distance, and not height, against time.

10.12.3 SUMMARY OF ANALYSIS OF VIDEO TAPE TRANSCRIPTS

One of the first issues to arise from the analysis of the discourse was he pattern of Chantel's utterances in particular. The way in which she combines her assertions with questions inviting acceptance or repair was instrumental in giving a lead to the group interaction on many occasions. There were further examples of the use of this technique by Claire and also by Philip in Group 2.

In the first two groups, at least one member emerged to give a significant lead to the group interaction and whose role is resonant with Vygotsky's notion of "a more capable peer". There is also evidence of the interchange of roles, especially in Group 1 between Chantel and Claire, which is resonant with Forman and Cadzen's (1985) notion of "complementary problem solving roles". There is further resonance with the findings of Hoyles, Healy and Pozzi (1994) that *navigated* interactions lead to the most effective learning.

There were several examples of Teasley and Rochelle's (1993) notion of a *collaborative completion* in both of the first two groups. However it did not necessarily imply that a JPS has been established by all members of the group, as illustrated in the first episode of Group 2 during which Jonathan was unable to engage with the problem. There was also a more complex example of such a category of discourse in which the collaborative interaction between Jonathan and Philip was distributed over more than a single sentence.

There was also evidence, in the second group, of the role of conflict in promoting constructive interaction which supports the findings of Johnson et al (1984). There is further support, in the case of this group in particular, for Johnson's et al findings that co-operative learning can be enriched by heterogenity among group members.

A major contrast between the patterns of interaction of the three groups relates to the way in which the third group in particular consistently failed to establish a JPS, despite appearing to interact successfully with the system. This finding supports the observations made by Atkins and Blissett (1989) although discussion takes place which looks like evidence of interaction it does not of itself guarantee effective learning. The level of discussion in this group was rarely about the problem itself, reflecting the dangers predicted by Hughes (1994) and Goldstein (1990) of a concern with the solution rather than the problem. There was little evidence of reflection in this group although this was one of the central aims of the design of the multimedia-based activity. The minimal level of interaction about the problem lends further support to the findings reported by Hughes (1994), of the need for reflective moments, and also those of Hoyles and Noss (1992) on the need for reflection on the mathematical features of the problem itself. The relatively low level of interaction in this group is also consistent with the Bennett and Dunne's (1989) observation of a relationship between interaction in the group and pupils' understandings of the task.

Another distinct difference, between this group and the previous two, was the way in which a "more capable peer" failed to emerge. A further particular feature of the interaction in this group was the minimal level of involvement of Vicki throughout although she remained in control of the mouse.

The problems associated with the effective functioning of this group point towards the importance of the role of a teacher in closely monitoring the quality of the process. They also serve to highlight the importance of teacher intervention. Although this group did request help, the intervention by the student teacher was brief and ineffective. Attempts by the pupils to intervene and to ask questions in order to clarify the nature of their difficulties were either blocked or simply ignored. The episode was probably counter-productive in the way in which it served to emphasise a preoccupation with the solution rather than the problem. This was in contrast with both of the other groups which had involved a significant level of intervention by the teacher-researcher in order to clarify the nature of the task and the means of controlling the software. Although not documented in chapter 9, details of these episodes are provided in Appendix 2(ii).

A major issue to emerge from the analysis of the development of Neil's understanding is the way in which this serves to illuminate Vygotsky's notion of the function of *egocentric* speech. The work of all three groups highlights the way in which participants in collaborative activity involving computer use are not wholly dependent on language to maintain shared understanding in line with the findings of Teasley and Rochelle (1993). This study highlights the major role for the multimedia system in supporting collaborative learning and in facilitating communication between peers, by providing a context for the production of action and gesture, which can serve both as presentations and acceptances. The simultaneous production of matching language and action can provide opportunities for acceptances of new ideas and also for repairs. Feedback from the system also fulfils the important function of confirming choices and bringing episodes to a successful completion. There is further resonance with the arguments of Jones and Mercer (1993) in relation to the the role of the computer as a medium for the facilitation of communication. This aspect is of particular significance given the importance attached to the function of speech from a Vygotskian perspective.

10.13.0 CONCLUSION

In this chapter the empirical findings have been summarised and related to the relevant aspects of the literature review. The conclusions, reflections and implications arising from this analysis are discussed in the final chapter of this thesis. The conclusions and reflections are grouped under the major themes arising from this study and the implications are considered in the final section.

11.0.0 CONCLUSIONS, REFLECTIONS AND IMPLICATIONS

The first two sections of this chapter are constructed around the major themes of collaboration, theoretical perspectives, the role of the teacher and the role of the multimedia system. The final section focusses on the implications arising from this study and also on the possibilities for further development.

11.1.0 CONCLUSIONS

11.1.1 COLLABORATION

The first conclusion that can be drawn from this study is that the use of collaborative group work using multimedia has the potential for generating high levels of pupil motivation. This phenomenon was apparent from early classroom trials in this study and became even more evident as the study developed. Further supporting evidence emerged from the overview of the successful use of IV in schools. This is echoed by other researchers with an interest in collaboration in general (see Johnson et al, 1984; Bennett and Dunne, 1989) and also, more specifically in relation to the use of multimedia, it is emphasised by Phillips et al (1995). The high level of discussion and interaction generated in such contexts is also commented on by a number of researchers (see Govier, 1988; Johnson, Johnson and Stanne, 1986; Wright, 1988), the implication of which also suggests high levels of pupil motivation.

The aim of this study, however, has been the investigation of the potential of collaborative learning using multimedia in the mathematics classroom, rather than simply that of collaboration. It is clear that collaboration and by implication, discussion and interaction, are pre-requisites for such learning to take place. However, this in itself is no guarantee that collaborative learning will occur. This danger is highlighted by Atkins and Blissett (1989) and this phenomenon was particularly apparent in Joanne's group during Cycle 3 classroom trials. Although a superficial analysis would suggest that the group members were interacting and talking in a constructive way, a closer analysis revealed that the level of discussion was rarely about the problem itself. For example, at its best most of the talk merely centred on defining the focus of the task and then on simply deciding which graph fitted, by a mixture of luck and guesswork. This confirmed the dangers predicted by Hughes (1994) and Goldstein (1990) of a concern with the solution rather than the problem and also reinforced the need for reflective moments (Hughes) and, more specifically, the need for reflection on the mathematical features of the problem itself (Hoyles and Noss, 1992). These problems highlighted the importance of the role of the teacher and also have implications for software design, both of which are returned to later in this chapter.

The need to be more specific in relation to the interpretation of the meaning of collaboration became apparent as the study reached its focus in Cycle 3. Teasley and Rochelle's (1993) definition of collaboration proved to be a helpful starting point for the development of a framework for the analysis of the resulting discourse in Cycle 3, since it is based upon an assumption of the type of behaviour which is expected to lead to effective learning. The resulting framework did provide an effective vehicle for analysing the discourse. In particular, it highlighted the way in which Joanne's group consistently failed to establish a JPS, with the result that the ensuing interaction was not about the problem itself, but rather about the solution or "right answer".

Even when operating within this framework, there was a danger of misreading the interaction as being of greater significance, in terms of learning, than appeared to be the case. For example the notion of a *collaborative completion* might be construed as providing specific evidence of collaboration within a JPS. This category describes an exchange which distributes a compound sentence over discourse partners i.e. one partner's turn begins a sentence or idea, and the other partner uses their next turn to complete it. For example, the interaction within Philip's group in Episode 2 about the cheetah provides an illustration. In this episode, there is evidence of collaboration, with a collaborative completion occurring between Philip and Neil at the start. However a JPS is not established between all members of the group, as Jonathan is clearly uncertain about the nature of the problem itself and remains so throughout. There is also an example of an apparent collaborative completion in a later episode involving the same group in which evidence of shared understanding is not at all clear. This occurs in *Episode 4: Aeroplane (continued 1)* when Neil completes Jonathan's sentence but in the context of considerable confusion on his part and also of evident conflict, in terms of shared understanding, within the group. In a further instance, the notion of a collaborative completion itself seemed to be too restricted and was expanded upon. This occurred in *Episode 3: High Jump (continued 1),* with the same group, when there was a high level of excitement during an interaction between Philip and Jonathan, which was accompanied by the use of coordinated language and gesture. This interaction extended beyond a single sentence and could be seen as a collaborative completion of a particular line of thought. It could also be construed as a *compound* or *multiple* collaborative completion. The framework itself was adapted to incorporate the important element of feedback from the system, in terms of facilitating the peer interaction and especially in bringing episodes to a successful completion.

11.1.2 THEORETICAL PERSPECTIVE

As this study has developed the significance of the socio-cultural perspective offered by Vygotsky has come to be increasingly relevant. In relation to the aspect of pedagogy, this has also illuminated the lack of any clearly formulated theoretical perspective with regard to the use of multimedia in mathematics in particular. In fact it has highlighted a tension which Norris, Davis and Beattie (1990) also note in relation to the use of computer assisted learning in general and which Brown (1993) articulates as a "clash of epistemologies" in a wider educational context. This aspect was reflected at the stage in Cycle 3 when evaluating *World of Number*. The intended mode of use of the materials was a source of uncertainty for both the teachers involved in the classroom trials and also for the researcher. It was not clear whether the materials were designed for individual, small group or whole class use. Problems were also encountered in relation to structuring the materials into the wider classroom context.

In addition the theoretical perspective guiding the development of multimedia resources has significant implications for the role of the teacher. This was also a major issue to arise through this study and which is considered in the following section.

11.1.3 THE ROLE OF THE TEACHER

The role of the teacher was in fact the first major issue to arise in the first lesson during classroom trials in Cycle 1. This related to the teaching style of the class teacher which was over-directive and prescriptive at the start of the trial period. This highlighted the importance of one aspect of the teacher's role in interacting with the class as a whole and in creating the conditions favourable to investigation, problem solving, discussion and collaborative group work. These were all strategies which underpinned the design of the classroom resources which had been developed by the teacher-researcher in this study. The experience from Cycle 1 in relation to this issue was the principal one in guiding the choice of school in Cycle 2.

As a result of the uncertainty with regard to the intended mode of use of *World of Number*, the intended role of the teacher was also unclear. This was reflected by the teachers in the trial school and there was little to guide the teacher on this aspect in the supporting printed materials. However in the introduction to the *Number Games* unit the designers seem to suggest a very minimalist role for the teacher. They suggest that the advantages of the video are that the students can replay the extracts at will and that the teacher is "freed to act as observer and counsellor". This minimalist role for the teacher is further emphasised with the suggestion that the "best ploy" for the teacher "may be to move quickly to the stock cupboard and let them get on with it!".

This view of the role of the teacher is in sharp contrast with that adopted in Cycle 3 classroom trials. There are a number of important aspects relating to the role of the teacher which emerged in Cycle 3 classroom trials. The first of these relates to the planning and structuring of the activities so as to take account of the whole classroom and the overall plan. This task was by the teacher researcher in consultation with the class teacher. The second relates to the ongoing interactive role, involving guidance, support, intervention and, at times, direction. Finally, a related issue which only emerged from the analysis of the classroom discourse was the importance of monitoring the nature of the interaction taking place.

With regard to the final issue in particular, an initial superficial analysis suggested that the members of Joanne's group were interacting and collaborating constructively, which closer analysis revealed not to be the case. This highlights the importance of the potential role for the teacher in terms of firstly monitoring the interaction and secondly in responding to intervene effectively. The intervention by the student teacher in this instance was ineffective and also probably counter-productive. The subsequent pattern of interaction did reflect that established by the student teacher. A more effective intervention at this early stage might well have resulted in an entirely different outcome.

11.1.4 ROLE OF THE MULTIMEDIA SYSTEM

The role of the multimedia system in this study has been that of a medium for the facilitation of communication between peers. It has supported collaborative learning by providing a context for the production of action and gesture, which can serve both as presentations and acceptances. As a result this study lends support to the findings of Teasley and Rochelle (1993) that participants in collaborative activity involving computer use are not wholly dependent on language to maintain shared understanding. Feedback from the system has also fulfilled the important function of confirming choices and bringing episodes to a successful completion. This model is resonant with that proposed by Jones and Mercer (1993) in relation to the the role of the computer as a medium for the facilitation of communication. This aspect is of particular significance given the importance attached to the function of speech from a Vygotskian perspective.

The evaluation of *World of Number* highlighted the extent to which most of the units did not fit the model of computer/multimedia system as being a *medium for communication.* The majority of the units contained stimulus material, which according to the designers were produced with classroom interaction very much in mind. However much of this interaction would not be with or via the system once the problem had been presented. In fact many of the units seemed to be designed as stimulus video and could well have been presented without the need for a powerful computer system, by means of standard video tape or a bar code reader device.

The unit *Running, Jumping and Flying,* however, did provide an example through which the potential of a multimedia system to become a *medium for communication* could be realised. A unique feature of this unit was the use of examples of motion from the real world using computer controlled video clips, which could not have been achieved through the use of any other medium. An important and significant aspect was also the element of feedback, which the designers of *World of Number* seemed to have tried to deliberately avoid in most of the units. Although this aspect did create the problem of pupils possibly becoming preoccupied with getting the "right answer" at any cost, it was also an important element in the situations where the pupils engaged with the problem and interacted more constructively, especially in terms of confirming choices and in bringing episodes to a successful conclusion.

A good illustration of how the system can act as a medium for communication occurred in the example referred to earlier from *Episode 3: High Jump (continued 1),* when there was a high level of excitement during an interaction between Philip and Jonathan. In order to repair the shared understanding with Neil, Jonathan uses language and gesture to describe the motion. He refers to her "starting like that", whilst making a wave motion in the air. Neil responds a little later on by saying "Like that", with reference to his sketch. Later in the episode Jonathan intervenes and continues with the statement that "She runs and she goes like that", at the same time making a wave motion in the air to signify the up and down motion of her initial run-up.

The interpretive framework of Teasley and Rochelle (1993) was influential in the development of the approach taken towards the discourse analysis in Cycle 3. However the study which they report on also has other parallels which are significant. Although they write from a science subject perspective, the focus of their computer environment could equally well be considered as being applied mathematics. Of particular note is the fact that not only is their approach to evaluation conducted from a Vygotskian perspective, but also as the designers of the software, so was their approach to the design. They outline their intention that their software both enables and mediates students learning. It is intended to enable students to construct qualitative understanding of velocity and acceleration and also to mediate their discourse about the meaning of those concepts for the activity of modelling motion. This approach is resonant with that adopted in Cycle 3 classroom trials, using *Running, Jumping and Flying* as a basis, although this resulted from the structure which was overlayed onto the software in this study in contrast to it being an integral part of the software design in that of Teasley and Rochelle.

11.2.0 REFLECTIONS

11.2.1 COLLABORATION

As indicated earlier, the focus of this study has been on the potential of collaborative learning in a particular context, rather than simply on collaboration. This distinction became increasingly clear during the development of this study. As a result of the analysis of the empirical findings of this study, combined with that of the ongoing literature review, a shift of attention from collaboration to discussion in the context of collaborative activity took place. However this interest was not reflected in the classroom trials in Cycles 1 and 2, as a result of the relatively low levels of interaction between pupils working with the *Domesday* system, for reasons already outlined. As the potential of the medium for promoting discussion was realised in Cycle 3, so attention shifted further towards the nature of the classroom interaction and in particular towards the quality of this. One episode also highlighted the potential role of conflict within a discussion for stimulating constructive interaction. This was the episode when Neil's group considered the cheetah and the social interaction became quite intense and heated as a result of Neil's challenges. The shift of attention towards classroom interaction was further informed by the development of a socio-cultural perspective which is reflected upon in the next section.

11.2.2 DEVELOPING THEORETICAL PERSPECTIVE

This study has highlighted issues relating to a number of theoretical perspectives. The tension and conflict relating to assumptions and expectations of multimedia (Norris, Davis and Beattie, 1990) can be traced back to the significant influence of behaviourism within the field of computer assisted learning, particularly in America. This is in contrast with constructivism in the tradition of Piaget, which Jones and Mercer (1993) consider to have been the most significant influence upon British education. This analysis highlights the individualistic conception of learning which underpins both of these perspectives. As a consequence the theoretical perspective offered by Vygotsky came to be seen to offer a framework which accommodates a communicative, culturally orientated conception of human learning.

The theoretical perspective offered by constructivism has been a significant influence in terms of developing a theoretical perspective. In particular radical and social constructivism, developed with specific relevance to mathematics education (von Glaserfeld, 1987 and Jaworski, 1994), have informed reflections on this aspect. A particular contribution of this perspective within mathematics education as a whole has been to shift the focus of attention on to the learner and his/her needs. This has been from an earlier tradition which was heavily dominated by behaviourist thinking, which involved a didactic approach to teaching based upon a transmission model of learning. However it offers little illumination on the role of the teacher and has come to be increasingly questioned as offering an adequate picture of the process of teaching and learning, both within the mathematics education community (Good, Mulryan and McCaslin,1992; Lerman, 1994 and Pozzi, Healy and Hoyles, 1993) and also more widely (Forman and

and Shavelson et al,1984).

As this study developed, the perspective in the tradition of Vygotsky came to assume increasing relevance and importance. The overall approach to the use of the multimedia system could be seen to be consistent with such a view and the research methodology adopted in relation to the focus of the study was significantly influenced by such a tradition (Mercer, 1991; Edwards and Mercer, 1987 and Teasley and Rochelle, 1993). The resulting framework illuminated the pupil-pupil interaction in particular and the perspective as a whole highlighted the crucial role of the teacher in this process.

11.2.3 THE ROLE OF THE TEACHER

The uncertainty about the intended role of the teacher in relation to the use of *World of Number* arose partially from the lack of clarity on this aspect in the supporting printed materials. However, as indicated earlier, from the few references to the teacher's role in the printed materials a quite minimalist view seems to be proposed. In writing about *Who stole the decimal point?* later, Phillips et al (1995) illuminate their thinking more clearly. They note that the teacher is asked, in the printed materials, to "manage and encourage their students, but not to give hints or answers". They observe that, in general, teachers keep to this but that when students become seriously frustrated by a problem, "some teachers find it difficult not to offer help". The latter comment, in particular, not only confirms a minimalist view of the teacher's role but also seems to envisage no role whatever for the teacher at a quite critical stage of the problem solving process.

The view proposed by Phillips et al is in sharp contrast to that which is consistent with a Vygotskian perspective and especially with his hypothesis, in relation to the *zone of proximal development,* that children would be able to solve problems with assistance from an adult or more capable peer before they could solve them alone. It is more consistent with the classical constructivist view of teaching which, as argued by Forman and Cazden, seen to be its decisive motive force from a Vygotskian view. It is also resonant with the view proposed by Jones and Mercer (1993) of the role of the teacher ("a la Piaget") as someone who simply provides rich *learning environments* for children's own discoveries in contrast to being someone who is an active communicative participant in learning.

A further comparison is offered by Crook (1991) who observes that a Vygotskian perspective implies an active role for the teacher in the learning process, in contrast with "current child-centred pedagogies (such as the Piagetian)" which tend to ascribe them roles which are merely facilitative. Interestingly Crook cites Fraser, Burkhardt, Coupland, Phillips, Pimm and Ridgeway (1988) when writing about models of computer-based learning, which have implications for the teacher's role. Fraser et al propose a model of computer-based learning which "frees up" the teacher to do other things. The authors propose a more consultative, counselling role which they argue seems to be excluded in practice for most teachers by their normal and necessary authoritative, didactic posture. Crook also compares this model with that which emphasises pupil *autonomy* and draws close parallels. Further reflections on the role of the multimedia system follow in the next section.

As indicated earlier, the role for the teacher seemingly envisaged by Phillips et al is in sharp contrast with that adopted in Cycle 3 classroom trials. This role was much closer to that of the *orchestrating* teacher proposed by Shavelson et al (1984), especially in relation to the integration of the content of multimedia-based work with the ongoing curriculum, and coordination of multimedia-based activities with other activities. Most of these aspects were planned in advance by the teacher-researcher in this study. Another important aspect of the teacher's role was in providing *scaffolding activities* (Bruner, 1985) for pupil learning to take place. One important strategy in attempting to develop these involved the use of peer interaction in the multimedia-based activities. A fundamental part of this process was the underlying intended structure of the activity. This was designed in such a way as to encourage the pupils to select and view a video sequence, think about the distance-time graph, sketch it, compare each others' ideas and then choose one to fit their ideas. They were also encouraged to explain why a particular graph does or does not fit, test out their choice and then to repeat the process with different axes. This **cycle of observation, reflection, recording, discussion and feedback** is summarised in Figure 13.

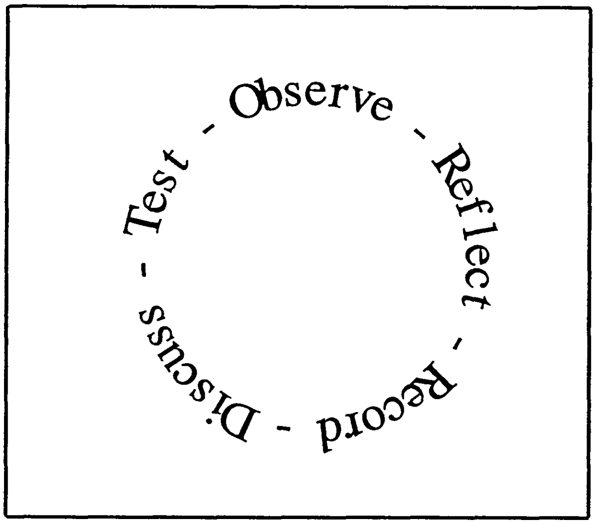


Figure 13

This model is consistent with approach of Hoyles and Noss (1992) in encouraging the pupils to reflect upon the mathematical features of the task and to consider precisely the mathematical ideas that are intended. The authors also make reference to the use of *scaffolding* material to develop pupil understanding. The empirical findings of this study have drawn attention to the importance of the teacher's role in monitoring this process. A further important aspect of the teacher's role in providing scaffolding for the development of pupil's understanding is that of direct interaction. A major difference in the experience of the group which interacted least effectively was the intervention of the student teacher, at the crucial stage when they needed assistance with both the control of the software and the clarification of the task. This intervention was not managed skilfully or effectively. In contrast there was a significant level of intervention by the teacher-researcher with the other two groups to ensure that they fully understood the nature of the task and also how to control the software, before they embarked on the tasks themselves.

This aspect of the importance of teacher interaction is also commented upon by the class teacher in response to being asked to consider some of the more difficult graph options. He commented on the need for teacher intervention in order to draw out the "subtle differences" between some of the graph options but also observed that "once you started to question them they could get to grips with it". This suggests the importance of teacher intervention in providing assistance within Vygotsky's *zone of proximal development* and is consistent with Bruner's (1985) idea in relation to the critical function of the teacher in *scaffolding* the learning task.

A further aspect of the teacher's role in providing *scaffolding* for the development of pupils' learning is illustrated by a development during Cycle 3 trials. This involved reviewing progress with most of the class after they had all had some experience with the multimedia-based activities, at the suggestion of the class teacher . He referred to this role in the post-trial interviews. He remarked that he would quite like to use the system with bigger groups as well in order to stimulate whole class discussion, because "there comes a point where you want to talk to the whole class or perhaps half the class to make sure they've got their understanding, with questions and answers". This model is similar to that suggested by Pozzi, Hoyles and Healy (1992), as a "scenario for optimal learning with computers". This is one in which the pupils first engage in mutual discussion with peers in the context of construction with the computer, then encounter the perspectives of other pupils in whole group discussion.

11.2.4 THE ROLE OF THE MULTIMEDIA SYSTEM

It is clear from this study that even when the role of the multimedia system is that of a medium for the facilitation of communication between peers, this does not necessarily ensure that collaborative learning will take place. Joanne's group provides evidence of collaboration and interaction at quite a superficial level, in contrast to the other two groups which were more successful in consistently establishing a shared understanding of the problem.

Also with regard to the successful establishment of a JPS in relation to the multimedia-based activities, the cycle of observation, reflection, recording, discussion and feedback was crucial. All of the elements in this cycle were important for the successful establishment of a JPS, of which the first and last were entirely dependent upon interaction with the system itself.

A lasting impression is of the quite exceptional power of the medium to support and sustain collaborative learning. The fact that groups of 14-year-olds consistently interacted with each other and the system for thirty minutes at a time to sketch, reflect on and discuss graphs of motion, in relatively unsupervised conditions, almost came to be taken for granted during the classroom trials. Teasley and Rochelle also make reference to this phenomenon when they observe that "in ordinary circumstances, one cannot imagine two 15-year-olds sitting down for 45 minutes to construct a rich shared understanding of velocity and acceleration". The major differences between this study and that of Teasley and Rochelle were the use of the video element and also the extent to which the structure of the activity was integral with the software design.

Finally the analysis of the discourse resulting from peer interaction during the multimedia-based activities system provided an effective vehicle for researching the development of pupil understanding, and also of misconceptions as illustrated by Neil's case study. A major issue to emerge from this analysis is the way in which it serves to illuminate Vygotsky's notion of the function of *egocentric* speech and consequently how this illuminates the direction of the development of thinking from the social to the individual. This is a central notion of a socio-cultural perspective and is in sharp contrast to the conceptualisation from a Piagetian perspective which is from the individual to the social. The implications of this perspective are considered further in the next section.

11.3.0 IMPLICATIONS

The implications arising from this study are considered in relation to the following aspects:

- the overall design of future multimedia resources
- software design in particular
- the mode of use of such resources and the role of the teacher
- the implementation, trialling and evaluation process

11.3.1 THE OVERALL DESIGN OF FUTURE MULTIMEDIA RESOURCES

This study has highlighted the rich potential of collaborative learning using multimedia. The empirical findings point towards the development of future multimedia resources which are explicitly underpinned by a socio-cultural perspective. Such a perspective has implications, not only for the mode of use of the resources, but also for the role of the teacher in this context which also need to be explicitly addressed.

11.3.2 SOFTWARE DESIGN ISSUES

The particularly unique feature of the multimedia software has been the use of video of motion from the real world as a focus for joint problem solving activity. Another important element has been the provision of feedback both in terms of confirming choices, or otherwise, and also in bringing episodes to a successful completion. However, successful interaction was dependent upon the engagement of the group members in the cycle of observation, reflection, recording, discussion and feedback. This cycle provided the structure of the multimedia-based activity, which was designed by the teacher-researcher in this instance and "overlayed" onto the multimedia software.

Given a similar perspective to that developed in this study, future designers of multimedia software resources could well address the question of how, and to what extent, the software might support and encourage the engagement of pupils in this cycle. For example, such a cycle could be built into the software design and made an integral part of the process of systems, verbal triggers be incorporated to remind pupils to sketch their ideas, and share and discuss these. These could be supported by visual reminders and the need to confirm that the relevant stage of the process had taken place before being able to progress further. Delays could be incorporated in order to minimise the problem of the "misuse" of the feedback facility. If options enabling the control and variation of such features were made available to the teacher, these could be adapted to the particular circumstances and capabilities of the various users.

11.3.3 MODE OF USE OF RESOURCES/ROLE OF THE TEACHER

A difficulty associated with the use of *World of Number* arose from uncertainty in relation to the intended mode of use. A further difficulty was the uncertainty in relation to the role of the teacher. The findings of this study point towards a more explicit theoretical perspective informing the development of future resources and also the role of the teacher . Resources designed with the explicit intention of promoting small group activity and interaction would help to remove much of the uncertainty related to the teacher's role.

This findings of this study in relation to the role of the teacher are resonant with that of the *orchestrating* teacher, (Shavelson et al, 1984). This role would be supported by the designers through the provision of suggestions and resources with the specific intent of facilitating the integration of the content of multimedia-based work with the ongoing curriculum, and the coordination of multimedia-based activities with other activities. This is in contrast to many of the supporting resources with *World of Number* which seemed to have been designed simply as follow-up activities, once the pupils had been exposed to the multimedia-based activities. The question of what happens prior to all the pupils being introduced to the system did not seem to have been entirely addressed by the designers. The resulting strategy of the teachers in the trial school was to introduce whole classes or relatively large groups to the software, which raises problems related to screen size, pupil involvement and also questions about the most effective use of the resources.

A fundamental part of the teacher's role was in the provision of *scaffolding* (Bruner, 1985) both in terms of integrating and coordinating multimedia-based activities and also in structuring the multimedia-based activity itself. An important strategy in this respect involved the use of peer interaction in these activities. The basis of this process was the underlying cycle of observation, reflection, recording, discussion and feedback

11.3.4 THE IMPLEMENTATION, TRIALLING AND EVALUATION PROCESS

A further problematic aspect of *World of Number* was the sheer scale of the project and the complexity of the resulting resources. Development work around just one of the resulting modules involved a large investment of time on the part of the teacher-researcher, which no classroom teacher could reasonably be expected to invest in evaluating such resources. This calls for the production of much more focussed resources in the future, together with the supporting suggestions and materials referred to earlier.

Finally in relation to evaluation, a consequence of the design of resources being underpinned by a socio-cultural perspective is the need for such a perspective to inform the process of evaluation also. The findings of this study are supported by those of Crook (1991) who argues that cultural psychology, in the tradition of Vygotsky, offers one of the strongest theoretical bases for the evaluation of computer-based educational activity. Further he notes that most evaluative studies of computer-based activities, like most of the practice they seek to evaluate, are based uncritically on an individualistic model of learning. He points to the fact that in most British classrooms, joint activity, involving pupils working in pairs or groups, is the norm and that socio-cultural theory appears to offer the conceptual framework most capable of dealing with this reality.

11.4 SUMMARY OF IMPLICATIONS

11.4.1 THE OVERALL DESIGN OF FUTURE MULTIMEDIA RESOURCES:

- to be underpinned by a socio-cultural theoretical perspective

11.4.2 SOFTWARE DESIGN ISSUES:

- video of motion from the real world together with computer control are unique features of multimedia which should be capitalised upon
- the provision of feedback is an important element which should be included as a feature of the software design
- the cycle of observation, reflection, recording, discussion and feedback was crucial and should be an integral part of the software design
- the use of verbal triggers, visual reminders and delays should be considered in order to reinforce this cycle

11.4.3 MODE OF USE OF RESOURCES/ROLE OF THE TEACHER:

- resources should be designed with the explicit intention of promoting small group activity and interaction
- the role of the *orchestrating* teacher should be encouraged and supported by the designers
- the role of the teacher in the provision of *scaffolding* should be supported
- suggestions should be provided on how the content of multimedia-based work should be integrated with the ongoing curriculum
- suggestions should be provided on how the multimedia-based activities should be coordinated with other activities.

11.4.4 THE IMPLEMENTATION, TRIALLING AND EVALUATION PROCESS:

- more focussed resources should be produced in the future, together with the supporting suggestions and materials referred to above
- evaluation should be underpinned by a socio-cultural theoretical perspective

11.5.0 FURTHER RESEARCH QUESTIONS AND POSSIBILE FURTHER DEVELOPMENT

The theoretical perspective and research methodolgy developed as part of this study would serve to illuminate the development of pupil understanding, and also common misconceptions, in a wide range of mathematical acivities. Contexts involving group work and the use of IT are particularly fruitful areas for future research. Further work could be done to illuminate the role of the teacher to an even greater extent by focussing on episodes of teacher-pupil interaction in the context of promoting collaboration and interaction between peers. Intervention skills which provide *scaffolding* for the construction of pupils' own understanding could be illuminated and thus the need for teachers to develop such skills be emphasised further.

The theoretical perspective developed as a result of this study is not simply of significance to the use of multimedia. It also has major potential in influencing developments related to the use of computers in mathematics education and also developments in general. The development of pedagogy and material design would benefit significantly from the influence of such a perspective. This is especially so at the time of writing this thesis, when calls are being made by leading university mathematicians for what amounts to a return to a behaviourist perspective and an absolutist philosophy in school mathematics. The basis for such arguments is the perceived failure of "progressive" theories of learning in mathematics education, which seem to be equated with the discovery approach of a "classical" constructivist perspective in the tradition of Piaget. The potential of a Vygotskian perspective lies not only in the compelling power of the theory itself but also in the fact that it offers a third way between two perspectives, both of which are perceived to have "failed" by many on each side of the divide.

In relation to the application of multimedia to the teaching and learning of mathematics, there is clearly potential for further development along the lines already suggested involving graphical interpretation in the context of development is that of 3-D geometry, an application of which is included on *World of Number*. However this particular application could well be produced as effectively by simply using computer graphics.

With regard to computer use more widely, a socio-cultural perspective could well inform developments across a range of applications. One area of particular potential is that of dynamic geometry software. The research methodology developed as part of this study could well illuminate the benefits to be gained in mathematics education from its application and give direction to the further development of associated materials, as well as to wider curricular and pedagogical issues.

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APPENDIX 1(i)

PUPIL MATERIALS AND TEACHER'S NOTES FROM CYCLE 3 CLASSROOM TRIALS AT SCHOOL C

CONTENTS

FORWARD PLAN

Lesson 1

START to FINISH dice game (Worksheets 1-3) - whole class activity.
Travel graphs (Worksheet 4)
Review slope of line/steepness of line.
Introduce the term *Variable*.
Discuss making the graphs more realistic i.e. changes not instantaneous.

Extension and/or homework: *Y2/p1/A1*
Y2/p2/Read and try A2 and A3

Lesson 2

Review of Lesson 1 (and extension/homework).
Emphasise graphs showing *relationships* between *variables*.
Discuss *linear* and *non-linear* relationships with whole class.
Introduce the IV disc to whole class - outline the context/activity
- Factsheet on 1988 Seoul Olympics

Run full screen of Women's 100m for whole class
What does the graph of distance against time look like?
Discussion/suggestions/sketches on board.
Use TEST facility to overlay graph onto full screen video.
Replay using PAUSE to examine particular features of the graph i.e.
time taken to get started, how long to get up to full speed?
What other graphs could we think about?
speed against time, other - acceleration?
Leave class to think about and sketch what the graph of speed against time might look like (opportunity to test ideas on the system in due course).
Explain arrangements for small groups - composition/approx timing.

Whole class to complete work from Lesson 1/work on *Y2/Section C/p6-7*
Small group(s) working at IV system.

Lesson 3

Review of progress with Y2.
Discuss *proportionality/non-proportionality* with whole class.
Whole class to continue with work from *Y2/Section C* and *to start Y2/ Section D*.
Small groups working at IV system plus follow-up activity.

Lesson 4

Review of progress with Y2.
Whole class to continue with work from *Y2/Sections C/D (also Section B - Discontinuous graphs)*
Small groups working at IV system plus follow-up activity.

Lesson 5/(6)

Review of progress with Y2.
Whole class to continue with work from *Y2/Chpt 1 and Y2/Review 1/p50*
Small groups working at IV system plus follow-up activity.
Overall review of all activities/display of posters.

Organisation of groups

Ideal group size - 3

Minimum time per group - 30 mins

Working on the system (and follow-up activity)

HELP Cards available:
Screen Controls (1) and Screen Controls (3)

Equipment needed:
Clipboards/paper/pencils
Large sheets for poster display/scissors/glue/graph paper

GROUP ACTIVITY Card (1)
GROUP ACTIVITY Card (2) for follow-up task.

START to FINISH - a dice game for two players

Aim To get from the START to the FINISH before your partner.

RULES

1. Take it in turns to roll a dice to move.

2. If you throw 1 then move 1 step towards the FINISH.

   If you throw 2 then move 2 steps towards the FINISH.

   If you throw 3 then move 3 steps towards the FINISH.

   If you throw 4 then do NOT move.

   If you throw 5 then move 1 steps back towards the START.

   If you throw 6 then move 2 steps back towards the START.

3. Record each of your own moves in the table on Worksheet 2.

4. Use a small counter or token to plot your progress on Worksheet 2.

5. The first player to the FINISH is the winner (or the nearest to the FINISH after both players have had thirty throws.)

Worksheet 1

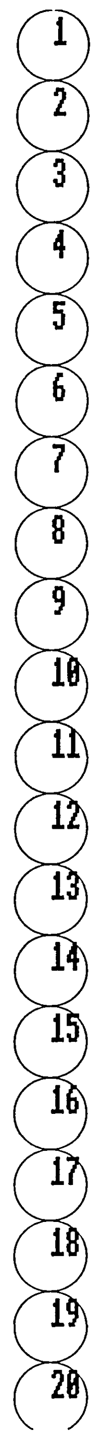
START to FINISH - a dice game for two players

Use a small counter or token to plot your progress from START to FINISH.

Record each of your own moves in the table below.

Move number	Dice score	Distance from start
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		
26		
27		
28		
29		
30		

START

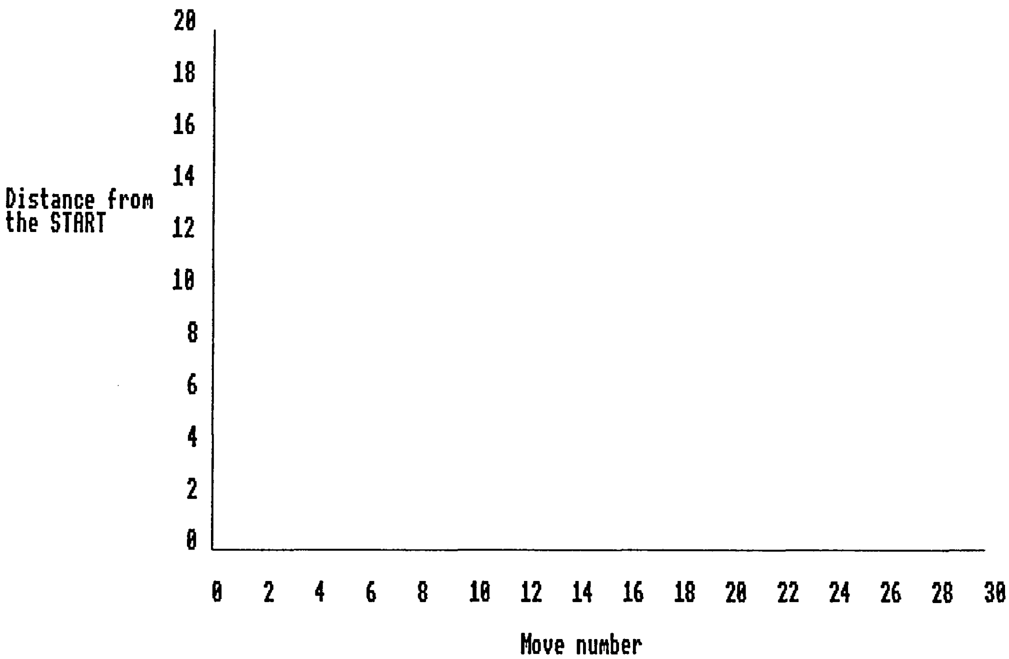


FINISH

Worksheet 2

Now draw a line graph of your progress from START to FINISH.

See the graph below to help you to set up your axes and scales.



Use your graph to answer the following questions:

1. What do the flat sections of the graph show ? ______________

2. What do the sloping sections show? (a)

and (b)

3. What do the steepest sections of the graph show?

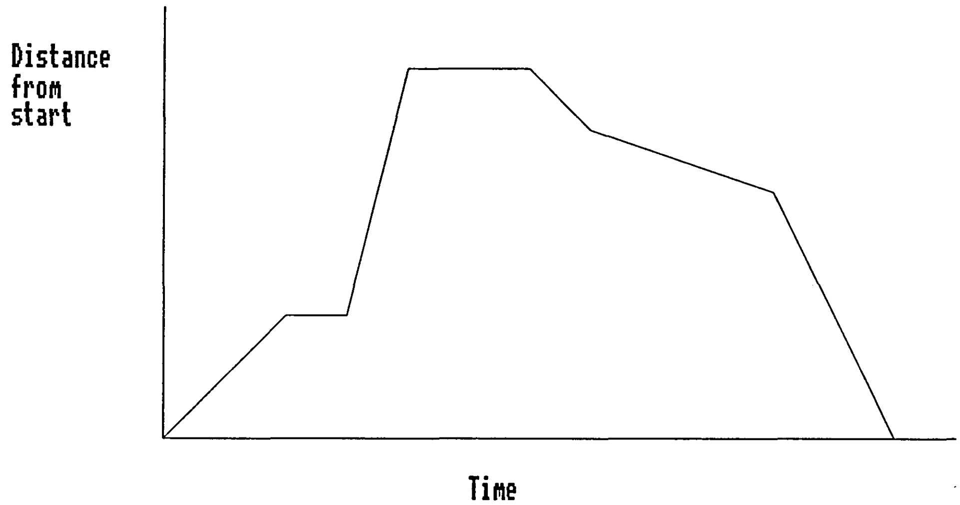
4. Compare your answers with your partner's and try to agree on these.

5. Try changing the rules of the game. Explain what happens.

Travel graphs Worksheet 4

1. Describe a possible journey shown by the graph below in your own words.

You will need to think about the scales on the axes also.



2. Sketch a graph which shows your journey to school from home each day.

Choose suitable scales and label your axes carefully.

Some things for you to think about:

What is the total distance (approximately) from my home to school?

How long does it take to me to get to school?

How do I show the differences between the parts of the journey when (for example) I am walking to the bus stop, waiting for a bus, stuck in a traffic jam, on my bike etc ?

3. Try out your graph on a partner to see if he or she can explain your journey correctly from your graph.

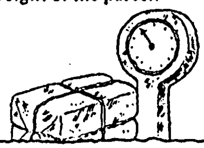
4. How might you make the graph in Question 1 more realistic? Show this by means of a sketch.

1 Relationships

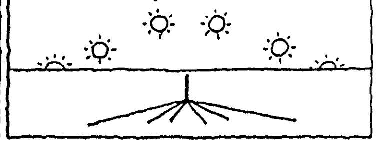
A Graphs

There are many circumstances in everyday life where one quantity is related to another.

The cost of posting a parcel is related to the weight of the parcel.

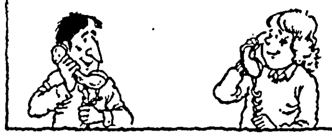


The direction of the sun is related to the time of day.

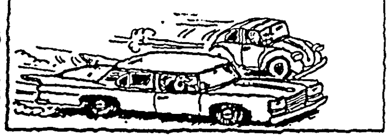


Often one quantity is related to several other quantities.

The cost of a phone call is related to the distance, the length of the call, the day of the week and the time of day.



The amount of petrol a car uses is related to the distance travelled, the speed, the size of the engine, and many other things.

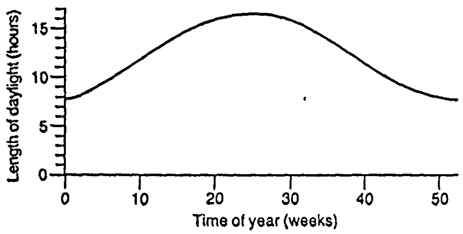


In this chapter we shall be studying examples where one quantity is related to one other quantity.

The relationship between two quantities can be shown in a graph.

This graph shows how the length of daylight in London is related to the time of year.

(The time of year is measured in weeks from 1st January onwards.)



A1 Describe briefly in words how the number of hours of daylight changes as you go through the year.

:s

:y whose value can change is called a variable.
:hows how one variable is related to another variable.

h on the previous page shows how the length of daylight' is related to ıle 'time of year'.

year' was plotted across.
ıf daylight' was plotted up.

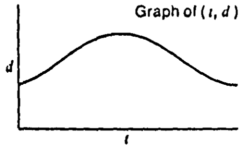
the graph

raph of (time of year, length of daylight).

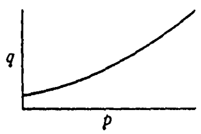
use letters to stand for the variables.

'e use t for 'time of year', and d for daylight'.

would then be called the graph of

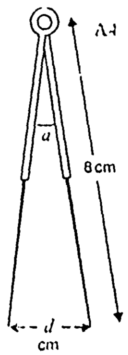


p and q are two variables, and this graph shows how q is related to p.
As p increases, so q increases.



Draw sketch graphs showing two variables p and q related in these ways (sketch a graph of (p, q) in each case).
(a) As p increases, so q decreases.
(b) As p increases, so q decreases at first, then increases.
(c) As p increases, so q stays constant (neither increasing nor decreasing).
(d) As p increases, so q increases at first, then decreases.

A train travels between two stations. It starts from rest (speed zero). Its speed increases until it reaches a maximum. The train travels at this maximum speed for a while and then it slows down to a stop. The time taken at the beginning to reach the maximum speed is greater than the time taken to slow down to a stop. Sketch a graph of (time, speed).



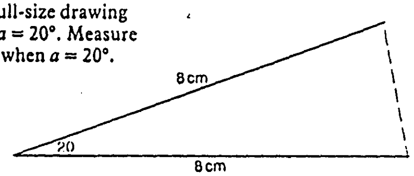
A4 The diagram on the left shows a pair of 'dividers'.

(It is like a pair of compasses except that it has two points instead of one point and a pencil. Dividers are used for marking off lengths on drawings.)

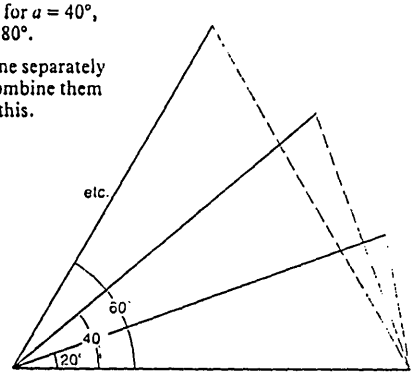
The distance, d cm, between the two points is related to the angle a.

(a) Think of what happens to the distance d as the angle a is increased from 0° to 180°. What do you think the graph of (a, d) will look like? Draw a sketch to show roughly what shape you expect the graph to be.

(b) Here is a simplified full-size drawing of the dividers when $a = 20°$. Measure the drawing to find d when $a = 20°$.



(c) Draw scale diagrams for $a = 40°$, 60°, 80°, . . . up to 180°.
You can draw each one separately but it is quicker to combine them in one diagram, like this.



Make a table showing values of a and d.

a	0°	20°	40°	80°	100°	. . . up to 180°
d						

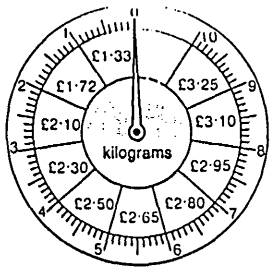
(d) Draw a graph of (a, d). Compare it with your sketch.

(e) What will happen to d as a is increased still more, from 180° to 360°? Draw a sketch graph to show what happens.

XI

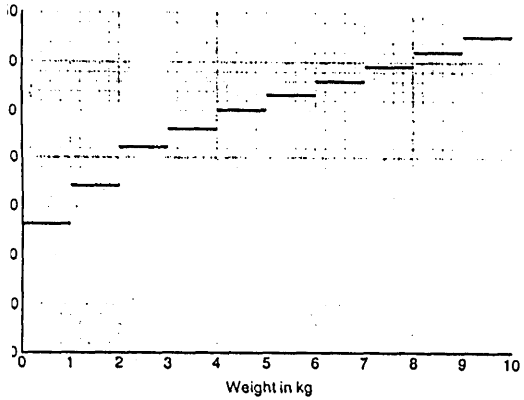
continuous graphs

ıe dial of a parcel weighing machine. the cost (in 1985) of sending parcels



ɛls weighing up to 1 kg, the postage Then the postage jumps to £1·72 ls weighing from 1 kg to 2 kg.

h of (weight, postage) looks like this.



ke this with 'jumps' in it is called a discontinuous graph.

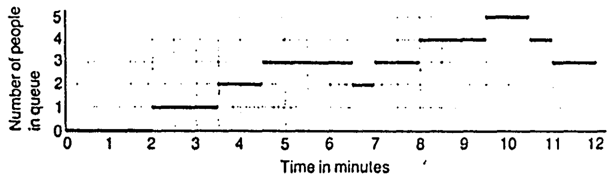
This table shows the 2nd class letter postage rates in 1985.

Weight in grams	Cost in pence	Weight in grams	Cost in pence
0– 60	13	300–350	46
60–100	18	350–400	52
100–150	22	400–450	59
150–200	28	450–500	66
200–250	34	500–750	98
250–300	40		

Draw a graph of (weight, cost of postage).

A taxi service charges 90p for distances up to 2 km, then an extra 50p for every extra kilometre. (An extra part of a kilometre counts as 1 km, so a journey of 3·2 km counts as 4 km.)
Draw a graph of (distance, cost of journey) for distances up to 6 km.

B3 The graph below shows the number of people in the queue at a supermarket checkout (including the person being served). Every time someone joins the queue, the graph jumps up by 1. Every time someone leaves, the graph jumps down by 1. (We assume that no two people join and leave at exactly the same instant.)



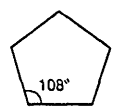
(a) At what times did people join the queue?
(b) Nobody left the queue before being served. How long did it take to serve the first person who came along?

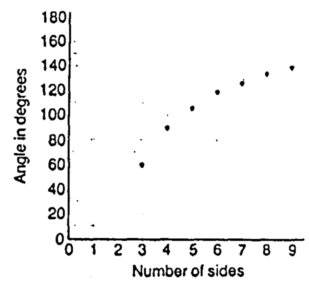
B4 Here is some information about another queue.
Draw a graph for this queue (like the one in question B3).

To start with there is nobody in the queue.
People join the queue at 1·5, 2·5, 4, 5·5, 6·5, 7 and 11 minutes.
People leave the queue at 3, 5, 8, 8·5, 9·5, 10·5 and 12 minutes.

Here is another kind of discontinuous graph.

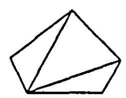
This graph shows how the size of the angles in a regular polygon is related to the number of sides. (For example, a 5-sided regular polygon has angles of 108°.)





The number of sides can only be a whole number (from 3 upwards), so the graph consists of a set of isolated points.

B5 Draw a polygon with 5 sides.
Choose one corner and draw all the diagonals from that corner. You will find that you have split the polygon into 3 triangles.



Draw polygons with different numbers of sides. In each case, choose a corner and draw all the diagonals from it.

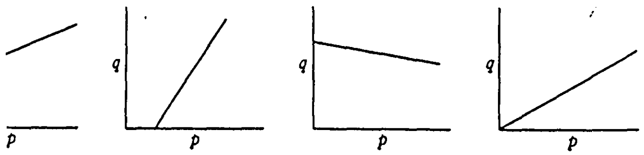
Draw a graph of (number of sides, number of triangles).

X

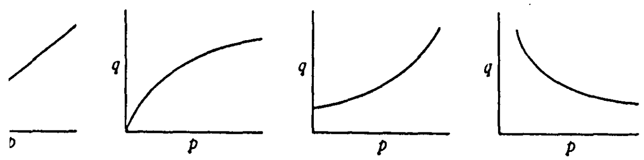
:ar and non-linear relationships

· on in this chapter, all graphs will be continuous.

elationship is one whose graph is a single straight line.
phs show linear relationships between q and p.



ıs below show non-linear relationships.

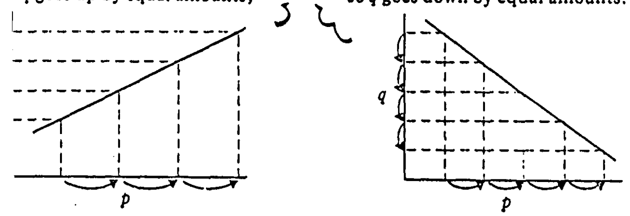


ere is a linear relationship between q and p . . .

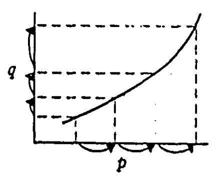
p goes up by equal amounts,
› q goes up by equal amounts,

or

if p goes up by equal amounts,
so q goes down by equal amounts.



: not happen in a non-linear relationship.
› changes by equal amounts, q does not.



C1 This table shows the length of a spring when different weights hang from it.

Weight in grams	40	60	80	100	120	140	160
Length in cm	6·6	8·4	10·2	12·0	13·8	15·6	17·4

(a) In the table the weight goes up by equal amounts each time. Is this true of the length as well? Is the relationship between length and weight linear?
(b) Draw a graph of (weight, length).
(c) Use the graph to find
 (i) the length when the weight is 105 g
 (ii) the weight when the length is 10·6 cm.

C2 (a) How can you tell from this table that the relationship between q and p is non-linear?

p	15	20	25	30	35	40	45
q	7	13	18	22	25	27	28

(b) Draw a graph of (p, q).

C3 (a) How can you tell that this table shows a linear relationship between s and r?

r	8	10	12	14	16	18	20
s	31	27	23	19	15	11	7

(b) Draw a graph of (r, s).

C4 For every 500 feet you go up a mountain, the temperature drops by 1 °C.
(a) Is the relationship between temperature and height linear?
(b) Make a rough sketch to show the shape of the graph of (height, temperature).

In this table neither variable goes up in equal steps.

p	12	20	26	28	36	42
q	30	42	51	54	66	75

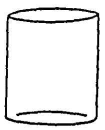
So you cannot tell from the table above whether the relationship is linear or non-linear. But you can find out by drawing a graph.

C5 (a) Draw a graph of (p, q) from the table above. Is the relationship between p and q linear or non-linear?
(b) Use the graph to complete the table below, in which p does go up in equal steps. You should find that q goes up in equal steps as well.

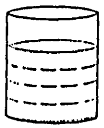
p	10	20	30	40
q				

XI

f a glass cylinder
arts empty.



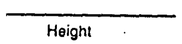
Water is poured in.
As the height of the water level goes up by equal amounts, so the volume of the water goes up by equal amounts.

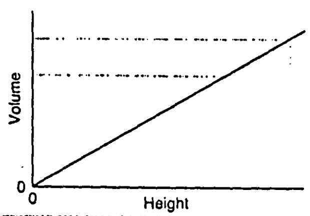


nk of the graph of the relationship between volume and height.

nd volume start at 0, . . .

. . . and as the height goes up in equal steps, so does the volume.

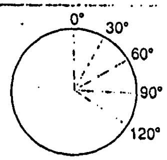


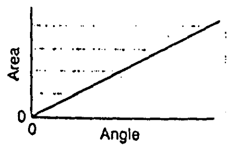


is a straight line through (0, 0).
volume is proportional to the height. This is a special kind
lationship where the graph is a straight line through (0, 0).

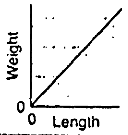
vo more examples of porportionality.

a sector of a circle
nal to its angle.



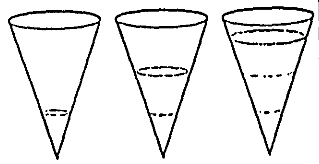


of a piece of metal wire
nal to its length
at the thickness of the wire
ll the way along).

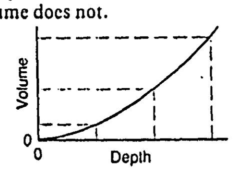


Here are two examples of non-proportionality.

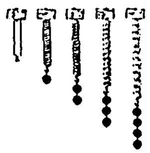
The volume of water in an upturned cone is not proportional to its depth.



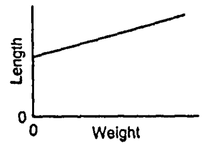
Although the graph goes through (0, 0), as the depth increases by equal amounts the volume does not.



The total length of a spring is not proportional to the weight hanging on it.

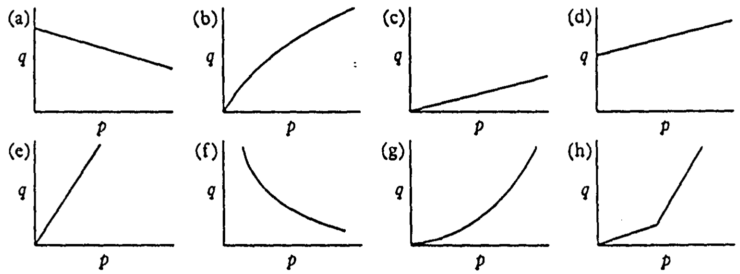


As the weight increases by equal amounts so does the length, but the graph does not go through (0, 0).



A straight-line graph which does not go through (0, 0) does not show proportionality.

In which of these graphs is q proportional to p?



(a) Copy and complete this table showing the perimeters of squares.

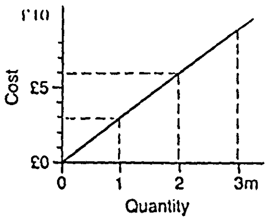
Side of square, in cm	0	3	4	7	10
Perimeter of square, in cm					

(b) Draw the graph of (side, perimeter).
(c) Is the perimeter of a square proportional to its side?

Repeat question D2 for the side and area of a square.

you buy a quantity of something, sometimes the cost is proportional
quantity, and sometimes not.

se you buy dress material which costs
etre.



metre you buy costs the same, and the
of (quantity, cost) is a straight line
h (0, 0).

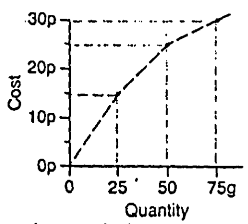
through (0, 0) because if you buy
s you pay £0.)

ase the cost is proportional to the
y.

k at these prices of bags of crisps in a supermarket.

eight	25 g	50 g	75 g
st	15p	25p	30p

t were proportional to the quantity, we would expect a 50 g bag
e same as two 25 g bags, which would be 30p. But in fact the
costs only 10p. And if we buy a 75 g bag, we get the next 25 g
p.



h of (quantity, cost) looks like this.

rough (0, 0) because 0 g costs 0p.
ot a straight line.

ere is not proportional to the quantity.

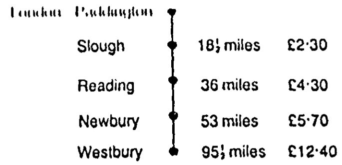
When a motorist buys petrol from a petrol pump, is the cost proportional to the quantity?

These are the prices a garden centre charges for grass seed.

Quantity of seed	Cost
3 lb	£1·35
5 lb	£2·25
10 lb	£4·50
12 lb	£4·80
25 lb	£9·00
60 lb	£19·90

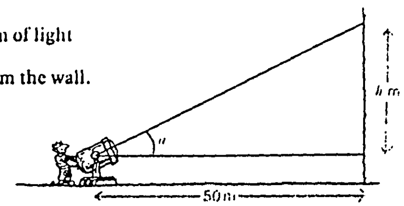
Is the cost of grass seed proportional to the quantity bought?

D6 This diagram shows distances and single fares (in 1985) from London to some stations on the main line to the south-west.



(a) Draw axes labelled 'distance in miles' across and 'single fare in £' up. Plot the points for the four stations.
(b) Is the fare proportional to the distance?
(c) Which station has the cheapest fare in relation to its distance?
(d) Which has the most expensive fare in relation to its distance?

D7 A searchlight shines a beam of light on to a vertical wall.
The searchlight is 50 m from the wall.



a stands for the angle which the beam makes with the horizontal.
h is the height in metres of the point where the beam hits the wall, measured from the level of the searchlight.

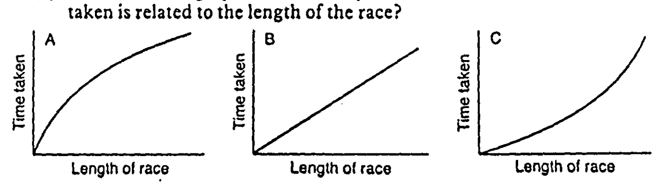
(a) Draw scale diagrams to find h when a is 15°, 30°, 45°, 60°.

Make a table.

a	0°	15°	30°	45°	60°
h					

(b) Draw a graph of (a, h).
(c) Is h proportional to a?

D8 Rajesh is an athlete. The time he takes to run a race is related to the length of the race.
(a) Which of these graphs is most likely to show how the time taken is related to the length of the race?



(b) Is the time an athlete takes to run a race proportional to the length of the race?

XIII

Factsheet

Some details to do with the olympic sequences.

Womens' 100 metres	**Florence Griffith-Joyner**	**USA**	**10.54 secs**	**NOR**
Best British Performance	Simmone Jacobs		11.31 secs	
Mens' 110 metres Hurdles	**Roger Kingdom**	**USA**	**12.98 secs**	**NOR**
Best British Performance	Colin Jackson		13.28 secs	(2nd)
Women's Long Jump	**Jackie Joyner Kersee**	**USA**	**7.40 metres**	**NOR**
Best British Performance	Fiona May		6.62 metres	(6th)
Women's High Jump	**Louise Ritter**	**USA**	**2.03 metres**	**NOR**
Best British Performance	Diana Davies		1.90 metres	(8th)
Pole Vault	**Sergey Bubka**	**URS**	**5.90 metres**	**NOR**
Best British Performance	Andrew Ashhurst		no vault	

(NOR - New Olympic Record)

GROUP ACTIVITY Card (1) Using the IV System

For this Activity you will be working as a group of 3.
You will need a clipboard, paper and a pencil.
Take it in turns to control the keyboard.

1. Decide on which video sequence you wish to view first and select it.
   See HELP Card *Screen Controls (1).*

2. Watch the video sequence and think about what the graph of *distance* against *time* looks like.
   Sketch your graph and compare it with those of the rest of your group.

3. Select the *distance* against *time* axes in Window C - see HELP Card *Screen Controls (3).*

4. Select your choice of graph from Window D - take it in turns to explain your choice and also your reasons for **not** choosing others.
   Then use TEST to see if you are correct.

5. Now select another set of axes for the same video sequence and repeat the process.
   If this is the only remaining sequence take it in turns to explain why you think the graph is the shape it is.
   Then use TEST to run the video sequence, using PAUSE to examine the motion more closely if necessary.
   Make a sketch of the graph.

6. Now let someone else take control of the keyboard and return to the main menu via MENU.
   Clear your previous selection using CLEAR, choose another video sequence and repeat the whole process.

GROUP ACTIVITY Card (2) Away from the IV System

Choose at least 3 video sequences around which to create a poster display.

Use your sketches to draw graphs showing relationships between, for example:

height and time
distance and time
speed and time
etc

Write some notes by each of your graphs to explain what each one is showing.

Screen Controls (1)

Select **Running, Jumping and Flying** from the **Perspectives** menu.

The following menu will appear:

1	100 METRES
2	110 METRES HURDLES
3	CHEETAH
4	LONG JUMP
5	HIGH JUMP
6	POLE VAULT
7	BIRDS
8	AEROPLANE

Choose up to four events

CLEAR VIEW MENU

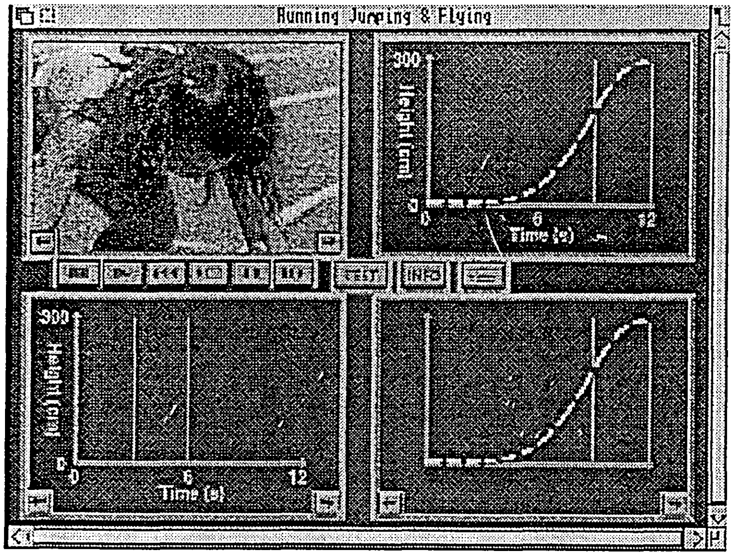
To choose an event click on it.

To remove a selection click again.

To clear all selections click on the 'Clear' button.

Click on 'View' to go to the four-window display.

Screen Controls (1)



These arrows let you step through the images.

Use the menu to make a selection from the different video sequences.

Stop

Play

Rewind

Play Big

Pause

Single frame advance when in pause mode.

Click on TEST when you think all four windows match.

Information

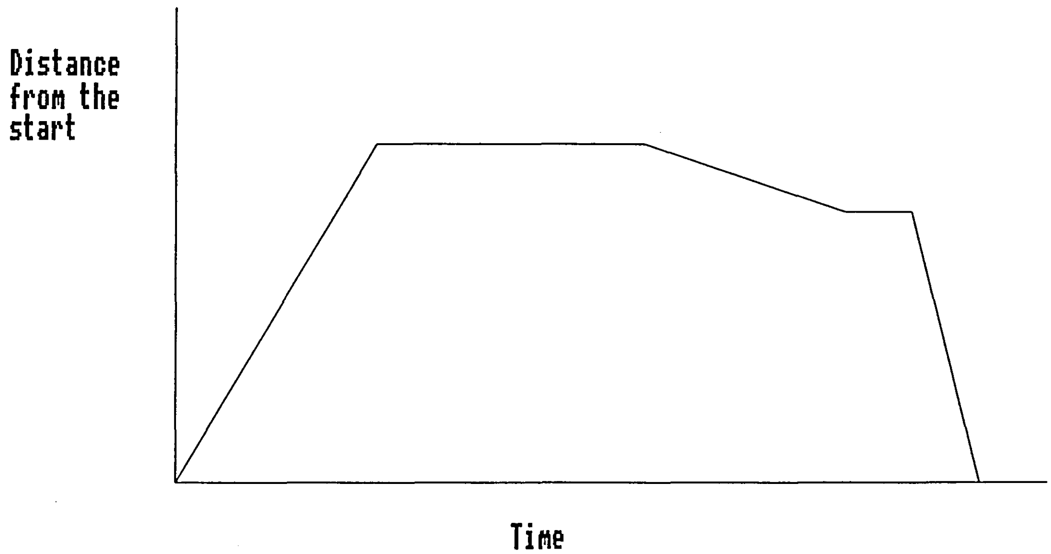
APPENDIX 2 (i)

DATA FROM CYCLE 3 CLASSROOM TRIALS AT SCHOOL C

CONTENTS

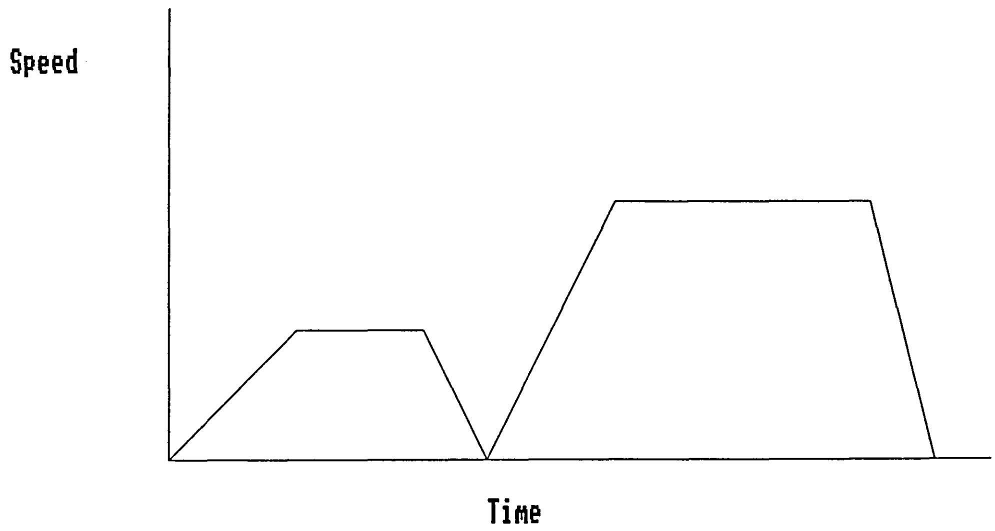
STORIES WHICH GRAPHS HAVE TO TELL (1)

1. Describe a possible journey shown by the graph below in your own words.
   You will need to think about the scales on the axes also.



2. Sketch a graph of distance against time which shows your journey into school and back again on a typical day.
   Explain your choice of scale on each axis.

3. Describe a possible journey shown by the graph below in your own words.
You will need to think about the scales on the axes also.

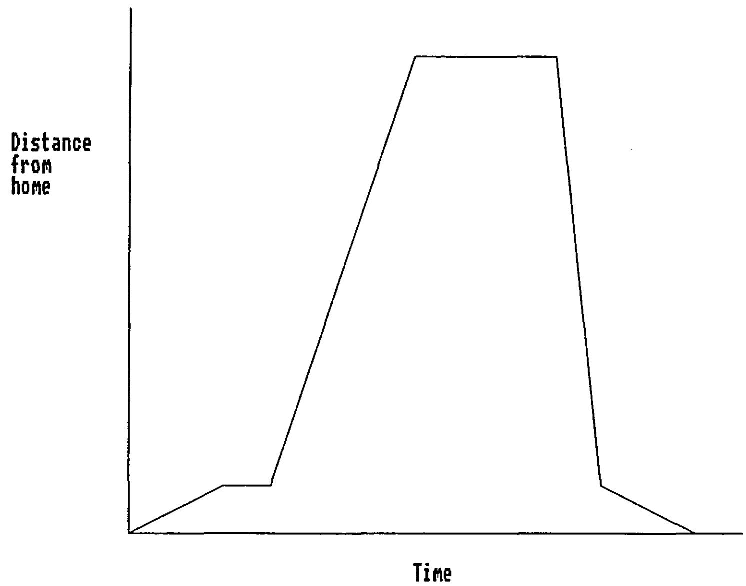


4. Sketch a graph of speed against time which shows your journey into school on a morning.
Explain your choice of scale on each axis.

Name......................

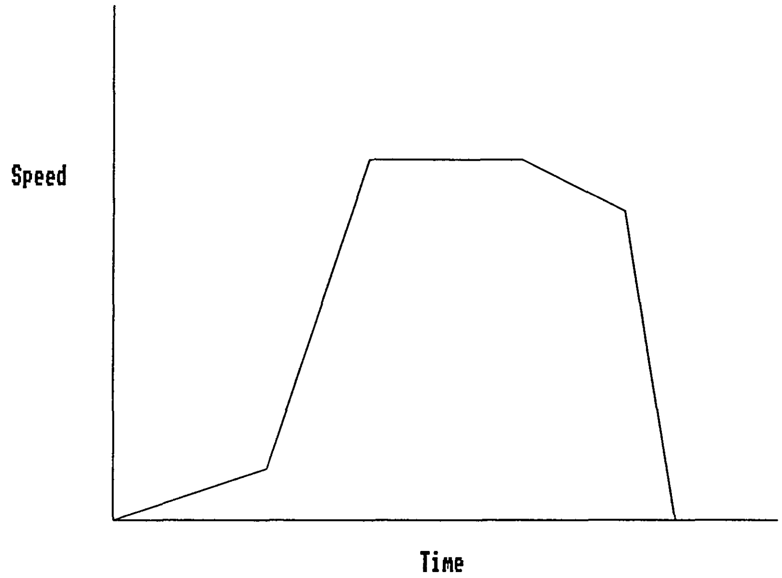
POST-TEST

1. Describe a possible journey shown by the graph below in your own words.
   You will need to think about the scales on the axes also.



2. Sketch a graph of distance against time which would show your journey from school into the centre of Barnsley and back again.
   Explain your choice of scale on each axis.

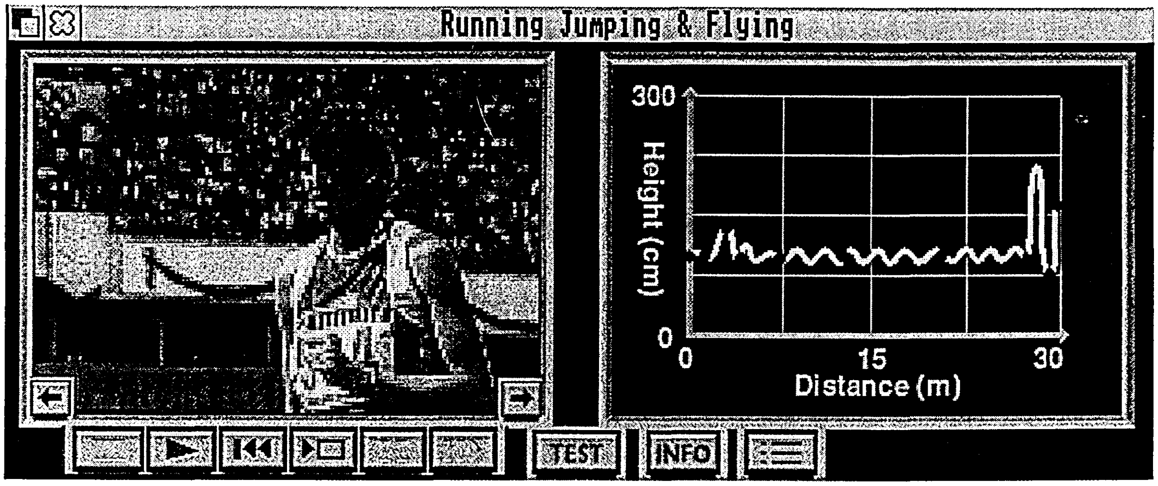
3. Describe a possible journey shown by the graph below in your own words.
You will need to think about the scales on the axes also.



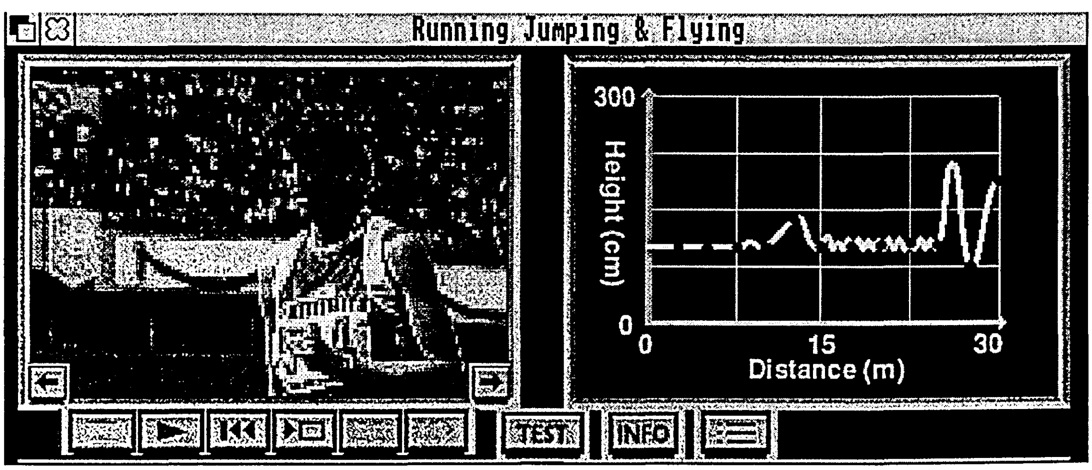
4. Sketch a graph of speed against time which shows a car slowing down as it approaches a set of traffic lights, speeding up again as they change to green and then suddenly stopping to avoid hitting a pedestrian who steps into its path.
Explain your choice of scale on each axis.

5. One of the following graphs shows Distance against Height for the High Jump.
   Say which one you think it is and why.
   Give your reasons for choosing and not choosing each one.

(a)



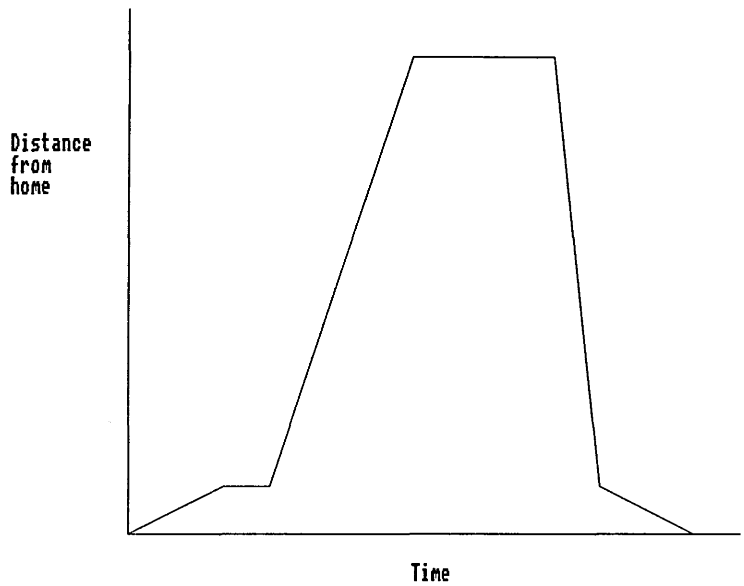
(b)



Name......................

DELAYED POST-TEST

1. Describe a possible journey shown by the graph below in your own words. You will need to think about the scales on the axes also.



2. Sketch a graph of distance against time which would show your journey from school into the centre of Barnsley and back again.
   Explain your choice of scale on each axis.

3. Describe a possible journey shown by the graph below in your own words.
   You will need to think about the scales on the axes also.

4. Sketch a graph of speed against time which shows a car slowing down as it approaches a set of traffic lights, speeding up again as they change to green and then suddenly stopping to avoid hitting a pedestrian who steps into its path.
   Explain your choice of scale on each axis.

GROUP INTERACTION PROFILE

General observations:

INTERVAL	PUPIL A:
	DIRECTING DIRECTED MEDIATING TALKING ENCODING WRITING ACTIVE LISTENING NON-ACTIVE
	DIRECTING DIRECTED MEDIATING TALKING ENCODING WRITING ACTIVE LISTENING NON-ACTIVE
	DIRECTING DIRECTED MEDIATING TALKING ENCODING WRITING ACTIVE LISTENING NON-ACTIVE
	DIRECTING DIRECTED MEDIATING TALKING ENCODING WRITING ACTIVE LISTENING NON-ACTIVE

General observations:

General observations:

PUPIL B:

D'ING
D'ED
MED
TALK
ENC
WRIT
A LIS
N-A

D'ING
D'ED
MED
TALK
ENC
WRIT
A LIS
N-A

D'ING
D'ED
MED
TALK
ENC
WRIT
A LIS
N-A

D'ING
D'ED
MED
TALK
ENC
WRIT
A LIS
N-A

PUPIL C:

D'ING
D'ED
MED
TALK
ENC
WRIT
A LIS
N-A

D'ING
D'ED
MED
TALK
ENC
WRIT
A LIS
N-A

D'ING
D'ED
MED
TALK
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WRIT
A LIS
N-A

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A LIS
N-A

Post-Trial Questionnaire

NAME........................

1. Did you enjoy working on the activities about graphs ?

   YES NO (please tick)

   Use the space below to give reasons for your answer:

2. How much did you like working in groups ?

   Very much Quite a lot OK Not much Not at all (please tick)

   Use the space below to give reasons for your answer:

3. How much did you enjoy using the multimedia system ?

   Very much Quite a lot OK Not much Not at all (please tick)

   Use the space to give your reasons:

4. (i) What do you think you learned whilst using the multimedia system?

(ii) Did the multimedia system help you to understand anything better?
If so can you say how?

5. What do you think you learned overall during the activities about graphs?
Say what you think you understand better if possible.

Thank you for completing this questionnaire.

(10.12.93 - ST)

BH

I've got some targeted questions that I would like to aim at but we could begin really if you want to just talk about how you have used the disc. Say anything which is relevant about how you have used it.

ST

Well initially I think we were slightly overwhelmed by the amount of material on the disc ... programme you can sort of home in on it and use it but there seemed to be so much on the disc initially that that was a bit of a problem selecting what to use and particularly because we hadn't been on the one day conference where we could have talked to other people who had used it and get the benefit of their experience. So initially it was having a quick scan through what was on the disc or the three discs or even the six sides of the disc and anything else we thought we could target. It did suggest that in the initial information we got that we aught to choose one particular bit and that was good advice and so we I suppose like most other schools homed in on the decimal point because that seemed to be the most interesting and so we spent quite a bit of time initially just familiarising ourselves. Also actually we just did run it with classes just let it run initially just to see their reactions and to give us a chance to use it. So we spent a lot of time initially trying to get the material and then we started to use it with classes. Initially we weren't sure how to use it whether we should direct it or what, so we were interested in that side of it. We wanted to try to get all staff involved if we could and they were quite keen big time investment to get to know the system. We used it with quite a wide range of abilities and the kids responded very well to it. What we realised fairly early on was that you have got to structure it. It is a very nice resource with a lot of potential but you really have got to get to know it to get the most out of it. You have really got to target it, structure it and build it in but we felt to some extent we had a bit of licence because we were pilotting it so we had to get to know the system. We could see that we really had to sort it out in the end, not just run it. You had to really think about how you had to use it. It would be very easy to use it an awful lot I think and there is maybe a danger that you use it too much almost. You have really got to be selective about what you want to do *staff using it and wide variety of groups and it has been very successful. We have grown in confidence in using it, particularly in the last two weeks. Staff have been fighting to use it. It got to the point yesterday for example one member of staff wanted to use it and the other one said, "Oh I was thinking of using it." It's nice when it gets to that stage.*

BH

Do you think it is the motivation aspect that is the key to it?

ST

Well it is certainly a highly motivating piece of equipment but there again anything new is. You have really got to work out what it is about it that is providing the interest.

BH

Is it the fact that it is new? Is that a factor? I don't suppose you have had it long enough to see if the novelty has worn off.

ST

No I don't think we have had it long enough. There are a number of factors. There are kids who are mad keen on computers and see this fantastic computer system and they are interested in that. There are other kids who watch a lot of television and think it's a television programme, an extended Neighbours, but kids aren't fools if they can see it is valid mathematically then I think kids generally like to think they are being taught well. If they can see it's not just that they are just being shown a video. They can see that it really is mathematically valid and they respond to that reason. In terms of motivation it is highly motivating but what exactly it is about it that provides that we have thought about it and we think it is to do with the fact that they are using kids of their own age, sort of peers. It is written at the right level. The interactivity is motivating. There is quite a lot of material on there that is not interactive and they still find that interesting, where it involves their peers. They are presented with a problem which involves their peers acting it out as a work situation and you know they are not maybe after that, interacting with the system, they still find it motivating. I suppose again it's because it is in a real life situation ... it's the fact that they ... that town or wherever, it's not just some mathematical models on a desk. It's a bit in the real world.

Could you think about some specific problems or barriers that you have faced. How have you overcome those? Can you think of any particular problems?

ST

I think the biggest problem is how to link it in with the scheme of work that you have got. I think the other problems you can overcome but I think from a Head of Department's point of view that would be one of my problems that I would not just want to see it used willy nilly, because I think if you do that then once staff have had a go with it, it is a novelty item, and then it tends to get left on the sidelines in future years, like OHPs and gather dust if you are not careful. Computers may gather dust if you are not careful. One of the problems is to build in, to sort out what's there and to pick out what you are going to use and build it into some scheme. There are problems with the hardware. Dave Smith has had quite a lot of problems on where they are moving on the lift between the floors, the system has crashed but with any computer hardware you use you tend to hit problems ... technical problems like that. In terms of maths problems, one is knowing which level - some problems are so open ended that you can use them with anybody. There are other problems where you have really got to think carefully about which group you are going to use them with. Some are more suitable for perhaps more able kids so maybe there is not a lot of depth in them.

BH

Is there a variation do you feel with decimal points, do you feel there is a standard level there?

ST

There is quite a wide variation - there are so many problems with decimal points. Mainly that is one of the attractions of it - the fact that there is such a wide variation, that you can pick and choose, in the end that is why it is suitable for such a wide range of kids.

BH

What about mode of use, what would you say has been the major mode of use? I am thinking of the whole class use, group work or individual, have you got a feel for the major way in which it has been used?

In most cases I think it has been whole classes. Certainly initially staff have used it in different ways and some staff homed in on particular problems, maybe two or three problems and have done it as a whole group exercise and others have started off initially like that and then they have left small groups to work on different problems and I think both methods are valid. You could argue for using both methods. I think you would probably want to use both. I think that when you split them down into small groups the kids get a lot out of it. There is the danger with a big group that some of them don't get involved. In small groups you can more easily get them all involved but you have got a bigger balancing act there when you more or less give them a free rein on these problems and they are all going backwards and forwards to the machines. You have got to be on the ball yourself to manage it and to provide a stimulus and asking a lot of questions. It comes down to time as well, whereas if you are doing it as a whole class exercise it is obviously it is easier to focus on particular problems. I suspect as we become more familiar with it we would move to mainly a method where we are working in small groups. It really in the end doesn't suit the whole class, the screen is too small, only one person can work the mouse, for various reasons like that.

BH

If you have used small groups have you had a feel for group size? Have you thought a lot about that? About the optimum group size?

ST

Well we have experimented to compare but not really the feeling I have is for half a dozen - its a good size. If you've got enough together ideas bounce backwards and forwards. I think one, two or three is not enough really is it? In a sense you are not making efficient use of it. If six are on it you can manage that it terms of getting the whole class eventually to have a go. So yes, a six here, a six there and a six there. If one or two are only on it then it takes a lot of time for the whole class to get round to having a go for one thing and you don't get the group dynamics with ones or twos.

BH

So the discussion isn't as much. You mention the fact that some things are interactive and some things are less interactive. Just *of is? Is it what you expected?*

ST

Well the interactivity is on two levels. I think in a sense some of them could be done just as easily on video but you've got more control or the control is easier I think on the system compared to video - replay, stop ... There's that sort of interactivity that maybe that's just control. But then there's the genuine interactivity where you trying out your solutions as in real time as it were on the system and that's affecting the next stage of your progress. In most cases its all about strategies, problem solving strategies and thats what you're trying to build up with a lot of material. How they solve one problem or what they do with one problem affects where they will go next. Its good for that.

BH

Going on to the video element what role do you think the video has actually played. How important has that been in the ... views?

ST

Well from the stuff that we've used mainly I'm not sure that its been used to its full extent and I can see on some material the video element would be more important because it gives you access to real life situations that you couldn't do in any other way. I'm thinking of the matching graphs, the running jumping, climbing - you've got the video playing landing and pole volting and to be able to - that seems to me that sort of exercise is really using potential in a good way. You've got real life situations, you've got the control to match graphs to a situation. You really couldn't do that in any other way. So thats very useful.

BH

Is the importance of the video ... ?

ST

In the some of the other problems the video is not so important because if you take a problem like the stepping stones you could set that up by worksheet, by OHP, by drawing something on the board and the video element is obviously more attractive I suppose and so it is important but its not so important as in the other type of problem. Again maybe if it were a bigger screen it would be better. So the video element varies I think - there's certainly some problems where its possibly minimal but again it is motivating to see it in video.

In establishing contexts, the real life aspect?

ST

Things like the ... although you simply play the situation, they like that one - we've never asked them why, we think it is to do with their peers doing it, it's explained in their language. The fact that they can see some of the kids have trouble initially and it's explained in their sort of language. The video swaps it round which you can do

BH

It gives me an idea for a follow up in terms of asking the kids why they are motivated by it.

ST

We have never got to where we have actually sat down and asked them but it's obvious they do enjoy using it. They really do want to have a go.

BH

To what extent do you feel that computer systems and software materials have actually promoted independent learning?

ST

Not to a great extent is the honest answer but that may be to do the kids have used it. I have seen examples where a couple of kids have sat down and I might have mentioned to you on a parents' evening. These were quite able kids and they sat down and solved this one point without hardly any help. They were Year 9, able kids and they worked quite independently on that and sorted it out for themselves, decided what they were going to do next, solved the problems. They had organised themselves and had all the right ... and so ... we're probably not organised to try that sort of learning out.

BH

You have got all the practical problems that you mentioned before about group size, etc. You were talking about two pupils working for quite a sustained period.

ST

They would have worked on it for a couple of hours. You could set it up to work independently.

BH

In designing the system do you think that was an aim of the

ST

I would imagine that they did have that in mind. There are bits of it where it would be quite difficult to do it on their own. You need a lot of teacher input. It goes back to one of its strengths - it can be used in a variety of ways - it is suitable in parts for independent learning but I personally wouldn't like to see kids just left to their own devices, teachers play a very important part drawing things together. For kids who are competent in using computers there is no doubt they can get a lot out of it. I don't know whether that is a pre-requisite ... computer ...

BH

What about less able? To what extent do you feel it offers access for less able kids, I am thinking in terms of ... What about younger kids and less able kids?

ST

Well I have used it with low ability Year 8 kids and again the motivating factor is good provided you choose the right problem. They have got access to these problems I think, they are presented in such a way that the low ability kids can get at them, but not all of them. You have got to be selective to some extent. Some of them aren't suitable so there is something for low ability kids I am sure and of course some low ability kids are very good on computers and they certainly thrive on it. Their confidence factor is very high. I have used it with a Year 10 group who are of maybe just a bit lower average ability, not what we call low ability but some of them are not that bright. They got on well with the system, again working at the right level, provided you may make sure that they have got a chance with the problems. They tend not to be very good at strategies and if you lead them in the right direction they do get a lot out of it. Once you nudge them in the right direction they get a lot out of it.

BH

It's entitled World of Number. To what extent do you think it actually offers something in terms of basic numeracy?

ST

I think it's quite patchy to be honest. I think it's very good for Ma1 - "Using and Applying" - choosing the right sort of maths, ways of working, communicating and responding. In terms of content for Ma2 I am sure there is a lot there but I think it is patchy and quite difficult to pluck it out if you were wanting to *number skills and basic numeracy. If you worked in that sort of way where you wanted to identify every little aspect relevant to the national curriculum it might be quite difficult because a lot of it is so open handed.*

BH

Do you think it would offer - I think one of the aims originally was to offer support to kids that perhaps were struggling with basic numeracy. Do you feel that it does offer that?

ST

Not to a great extent. I think it would be part of a strategy so maybe it's valuable from that point of view. I am not sure I could say with hand on my heart that if kids were really struggling with numeracy that if they used that system a lot they would come out an awful lot better. They would come out better in terms of their understanding things but more to do with problem solving strategies. I wouldn't have thought with numeracy itself unless you directed it that way. You wouldn't want in the end just to plonk kids in front of a system, you would want to go away and work on it, you would want to follow it up. You would want to do preparation and provided you structured that in the right sort of way I suppose you certainly would. In itself ...

BH

That has more or less covered all the points I wanted to make. Are there any other points that you feel that have arisen that would be of interest?

ST

No ... I think that equal opportunities you need to think about that, because it's a computer system if you're not careful the lads can take over responding to whole group work ... boys can become dominant. Girls interest is ... careful nurturing and if you do that then I found that the girls are ... the ones you get just as much out of it. I think there needs to be an awful lot of work, more work done on support materials. I think they are quite weak. Although the performance ... but when you actually get down to it if you could ... a little bit out of it. The worksheets are not quite useless but are not particularly helpful either. Although its obvious that some attempt has been made to help teachers ... in terms of actual use in the classroom if schools were given this system they need to put quite a bit of work into the overall management and planning of use in terms of seeing it work, in *should follow.*

BH

Like a teachers support material which isn't there at the moment.

ST

No I don't think it is there but its been ... I suppose ... there's so much material there ... couldn't do that. You could take decimal point which is clearly the most popular ... group to work on maths could come up with some really good material. I think the worst thing you can do is to leave kids in mid-air with this. You really do need to follow it up and come to some conclusions, in a sense that's the motivating factor, it does ... to some extent these computer games ... solve problems, move onto a level ... you have got a definite focus, that's one of the good things about it, it provides a real focus in decimal point anyway, where each individual problem is part of a range of problems. You solve those and you move onto this next level and you have to solve another problem there. It provides a real focus for the learning ... It is expensive, if we had to buy a system you have got to think of the cost ... We have been given the system, if we had to buy it - certainly as it stands at £2,500 it would be very difficult to justify in Rotherham - possibly the two systems ... equal systems. You might be looking say at £1500 ...

BH

... to work that one out. I suppose it comes down to priorities really - what is a realistic price.

ST

I suppose its got to be part of a whole school policy if something like that is too expensive for the maths department to purchase then and also you have to say that having bought it you probably don't use it more than ...
Having used it though we'd be very sorry to see it disappear.

BH

You've actually invested a lot into it.

ST

I think our major priority is to develop some way of working with it which has some logical progression. We don't want to use something with Year 7 kids and then do something for one year and get a year right and say we're going to have a look at this and then they all say we've done this before. You've got to plan it

That's quite a major issue really, it takes some sorting out.

BH

What commitment have the authority given to you in terms of how long you've got it for. Is it yours in - permanently? Do you have to justify keeping it?

ST

Well my understanding is that we will keep it providing we are making active use of it. Thats not been put down in writing but that's the understanding. NCET have said that that's what the authorities are doing provided we can make out a good case for keeping it. In a sense that having built up the expertise, invested so much time it would be an ... to move it somewhere else.

BH

Particularly ... what you're saying about needing to match it across the years, have activities running across years, building in some sort of direction.

ST

What I've offered to do - have set up is to run some INSET courses and offer them to other schools in the county so they can get the benefit of our experience which is building up all the time of course. So that if they get some money to purchase a system then they'll want to do this or even to provide the stimulus for them because until you've seen this you don't actually know what you want a system. We've had another school here already ... of course they'd no idea you could do this sort of thing with technology and once you can see what you can do with it then you think well we could do with a system. So we're hoping to keep it.

BH

Well thats all my questions - thanks very much.

BH

What I'm really interested in - I've got some points I'd like to pick up but really it would be useful if you could sort of outline to me how you've used the system and really immediate responses, reactions and thoughts about it.

BJ

You mean what range of kids or anything really. Well firstly we experimented with all ranges 7, 8, 9, 10 and Year11 ... mainly to familiarise ourselves with it - find out which was more suitable for which age group. Stuck mainly with decimal point but I found that a lot of the small ... were useful starting points like the Bottle Crates and the little ones like the one on the House problem, the garden, the park. They are nice starting points - there's a lot of scope here but we haven't used ... Labrynths is one that I've used as a class - ... one ... but it was first one mapping labrynth ... the map one and then we did the orange one as homework. The lead off from that was to map the labrynth then go away and come back with a strategy. Ideally if you've got enough at one machine, say four, you could get a lot more out of that.

BH

So in terms of - what do you think is the main barrier to greater use ... ?

BJ

The size of the screen - if you could actually put it onto a large screen you would see it better but you can't have thirty kids around one machine. What you've got is something like the week before last where you've got to pick a puzzle and let some go away and work on that and some work on another one then come back and see the results then. That I've found is a good way. Last year with decimal point we did it that way ... let them find a puzzle - go away and work on it and then come back. I think that we did about eight of the puzzles last year doing it that way.

BH

So how would you set something like that up if you've got small groups coming - how do you begin the process?

BJ

Introduction to Decimal Point - show them how the machine works and how they can get from puzzle to puzzle - how to search *for a puzzle by using the magnifying glass- show them that they've to find a puzzle. Some of them could work on the machine - some of them could work away - explain that they all can't work on the same puzzle at the same time and then say "Right first stage to count the bill". Now you need photocopies or to produce bills for that worksheet, go away and work with that and then come back. The next one - the Cube - go away and work with that. Some of the ones which are interactive ... you've got to have them working at the computer all the time and that ties it up - it can't be used with others.*

BH

So it's quite a high degree of management really?

BJ

You've got to think about how its going to be used who is going to use it how they're going to be using it at that time. It's a good stimulus.

BH

In terms of independent learning how do you feel - does it promote independent learning? That's quite a managed situation.

BJ

Independent learning - well it teaches them the different ways of solving a problem, looking at the problem, going away and working on it. It's the interactive one the ... that its wrong - like with the Dress - it tells them something else. Or, Boat, it tells ... them that the front boat come back to get the right one. The next thing is the different answer each time if you switch the machine off and start again. Could be a different one to feed in ... the dress.

BH

I think I was more thinking of do you see it as something that more or less the kids could just be left to their own devices with? Do you think it would work in that way?

BJ

It depends on what ability you're talking about - I don't think I'd like to try it with the ones I've got at the moment - the low ability ones - I don't think that would work - I think you ... yes - the low ability, no! Not on Decimal Point - probably on some of the others, yes, like for example the coloured blocks, the towers. I think that could be a low ability one to leave them just to work *on. The ... limited that would just make one colour say blue you've only got about twelve different views to match up not using the full scope.*

BH

Just thinking about that the low achievers - one of the aims originally was to provide support for kids that were having difficulty in terms of basic numeracy. What do you feel the system offers in that area?

BJ

Well I haven't tried that challenge in that one - look's as though it probably would be challenging in that one. I think you could with Labrynth - set that up for whatever ability you wanted to. I'm afraid we haven't gone into that writing ... etc. yet.

BH

So that would be quite time consuming.

BJ

The ... are made out ... that you make sure that you've got the room conditions correct - I think that one would be ... I use that one with the more able - that Powers of Ten. That's worth showing - standard form.

BH

So how did you use that - was that with a full group?

BJ

That was with a whole group with a demo. We were doing standard form and it seemed a nice way to introduce the idea of large numbers. There again it's lost with being on a small screen. If there is some way you could actually link the monitor to a large TV screen or a number you could show that all the way round - it would be nice. It loses it by being a video because you haven't got control that you have on the interactive. That's the advantage of that you can divide by a number and see the instantaneous change. You couldn't on a video. I think if you could lengthen eg. get the multimedia at the front and say two other monitors further down round the room that could be linked I think that would be more use.

BH

Probably technically possible isn't it? It's the cost of investing. In terms of the major mode of use would you say that you mainly used it with whole classes or small groups - which would you say was the predominent mode of use?

Whole classes and then go off and work individually. I think thats where it happens. I've not tried it with the idea of just a few working on it while someone was doing something else. I think its a distraction with it being there others are wanting to see whats going on.

POST-TRIAL INTERVIEW WITH HEAD OF DEPARTMENT (ST)

BH

If you want to give any general reactions and then anything I feel that youv'e not covered on my list I will come back to.

ST

In general we think the system has got enormous potential and the obvious ways to use it probably, initially, are in the investigational work and that was where we put a lot of our effort initially in using it. It certainly motivated the kids - they were very surprised by the fact that they were seeing video images - they're used to seeing computer images and using computers. In the school, in maths in fact, that they were seeing video and the fact that they could control it with a computer was quite a novelty for them. It really engaged their interest, I think - so it fitted in quite well with the approach we take with investigational work and we tended to use it maybe in a circus arrangement with some kids on an investigation, paper-based in the classroom with others on the investigation to do with the interactive video. But then in a sense that becomes quite limiting in terms of what you can do with it so I was interested in how you could integrate it more into the content of what we do. I thought that's probably where the real potential lay with it. So I would be very interested in what we've been doing with the work on graphs - to have a look at that because I've not really got to grips with that - because that involved a real committment in time which you put in, to some extent, to a large extent I think ,which I appreciated and it was with the investigation stuff you could almost say from day 1 "We are going to look at this and do an investigation" In a sense, although you ought to have looked at it before hand, it's fairly easy to have a quick look one lunchtime and do a lesson in the afternoon on it, so you can make fairly quick use of it in that sense. But to get the most out of it you really need to invest, looking at it in more depth, which is probably what we are going to do to a large extent, so I certainly appreciated that and I think we found in working with that Year 9 group that it's got real benefits. In a sense you only need to do it once of course because once you've sussed out what it's about you've got potential to use it with other groups and other years. So it's like any other resource once you've sorted it out and planned it into a scheme of work, then it works ...

BH

Is that initial investment of time the big barrier?

ST

Well it's one of the considerations - you've got to have someone committed to doing that - also you've got to have a department that's willing to give things a go and I think I'm quite lucky in that most of the people in my department are quite willing to do that - they don't always feel very confident about using it but they're used to kids using computers in their rooms and they realise that often some of the kids know more about computers then they do. Provided they can get them going initially then the kids are able to organise themselves.

BH

Has the work with this group generated interest from the rest of the staff.

ST

Well they've expressed an interest in it - I'm not sure yet because, to be honest, I've not yet tried to devolve the work we're doing down to other groups - so that's something for the future - so I think it would be fair to say yes, it has. Although the parallel group that have done the preliminary tests I think ... all things being equal would have been very prepared to use it.

BH

In terms of the groupings, I pressed for quite small groupings, three, and I suppose in the longer term there are some possible limitations with having smaller groups but I was just interested in your reaction to the fact that there were groups of three, and not say groups of five or six.

ST

Well groups of three means it takes longer to get people through and there's maybe less, well it's difficult, there may be less scope for interactions, depending on which three you've got. Maybe four or five or six might give you a bit more scope for discussion but then on the other hand it might crowd people out because then there's too many and you can't always get ... so thats been quite interesting. I felt, I don't know what you felt, that I found that three interacted quite well and it is a good number to use.

BH

I was quite pleased at the level of interaction that I had on the sections that I had videoed.

I would quite like to use it with bigger groups as well, with whole class discussion, because there comes a point where you want to talk to the whole class or perhaps half the class to make sure they've got their understanding, with questions and answers, and it's nice to be able to have the system there but it's then a problem that you've got a small screen and that is quite limiting in the end. You've got kids ... who can't see whats going on.

BH

One system in a classroom is an awkward number - I mean you now actually have the facility, if you buy the CDRoms, of using two systems. Do you think that would make it more likely to be used more if you operate on, say, a two system model.

ST

I'm sure that that would be a real help because you can have a couple of groups working it - it means it somehow integrates better. You know if you've got one group of say three working on it, then the others think "Oh I'm never going to get on that" but if they can see ... two systems ... but its quite expensive running two systems.

BH

But I mean you're virtually there, aren't you?

ST

Yes I just need the discs. Well yes, but a lot of schools would be struggling to invest in one system, never mind two - I think we've been quite lucky in that respect.

BH

I suppose for some applications it might make sense - whereas we were spending thirty minutes, more or less, with each group - I suppose for some activities it might make sense to say have them for ten or fifteen minutes - you might actually have had enough time at the system.

ST

Yes for ten minutes depending on what you're doing.

BH

In terms of the graphs that they were asked to interpret, the speed against time, distance against time ... there were some options they could choose, distance against height, I think it was - what did you think in terms of the level difficulty in that as an option

ST

Well I think without teacher intervention, I don't think they appreciated the difference - the subtle differences between the two, between vertical height and distance, and vertical and time, for example, and so it certainly needed some teacher intervention to draw that out but I think ... the subtle differences are quite difficult to appreciate, just on their own I don't think they would have thought about them. But once you started to question them they could get to grips with it - the fact that the distance one stopped at the end whilst the time one went on - they could see that (by running the video).

BH

and it ??? very difficult to deal with if you didn't have the video as a back up.

ST

The fact that you could compare the two graphs instantly ???? that one stops that was very good.

BH

I think that's really <u>most of it.</u> Their reactions as working groups were very positive. I just feel from observations that was quite effective part of the experience for them. Do they work in groups as a norm or is that novel?

ST

It's probably quite a novelty in the sense that to go away to another acticvity and work in a group, as on the computer. They're used to working in twos or threes or fours. They don't work in silence, individually, so to that extent they're used to working in groups and they talk about questions in groups but it was the fact that they were working on posters, working at computer, the fact that they were doing that in groups was the novelty.

BH

... Is there anything else you feel ... ?

ST

The only other thing I would mention is the fact that the activities certainly need structuring and the worksheets that are available I'm not sure are ideal. I think they still need a lot of work done on the worksheets side.

INTERVIEW 1: CLAIRE AND LAURA

BH

What I want to do is talk about the two weeks we spent working on graphs and the first thing I would just like you to think about is everything that you did from when we started with the dice game ... "Start to Finish" and could you just say what you felt about the work that we did, what you particularly liked and what you didn't like?

P

Liked work on computers best.

BH

Why?

P

Just interesting.

BH

What was it that made it interesting?

P

It was good to do something different because we were always working from text books.

BH

So one it was different - we'll come back to that.
In general would you say do you enjoy the work overall - the two weeks.

P

Yes

BH

I don't know if you normally work in groups but can you think about some of the activities you were in a group of three and for other activities you worked with two. How did you feel about working as a group?

P

Liked working as a group because you can like ...

BH

And is that something that you do normally or is it unusual?

Well we do have ...

BH

But you're not actually asked to work in a group.

P

No.

BH

But you tend to talk to one another?

...

BH

How big will a group be - will it be just the three of you?

...

BH

You say that you enjoyed using the computer - can I ask you to think about what you actually learned whilst using it - just think about some of the activities that you were doing - what do you think you learned or perhaps did it make you understand anything better or understand something that perhaps you hadn't understood before?

P

Working out what graphs would look like - it helped when we put the graph across the screen, when it was playing it - it showed what was happening.

BH

You found that helpful?

P

Yes.

BH

Do you think it added something? If you had been doing those activities - if I said to you you'd got to imagine a plane landing and draw the graph of, say, distance against time do you think you would have been able to do that.

P

????

BH

Do you think you could now?

Yes.

BH

So what was it about the system that helped you do you think. Was it the drawing the graphs afterwards or was it something about looking at the sequence.

BH

Yes it was ??? and sequence as well.

BH

So there were the two things.
How much work have you done before in graphs - have you done say a distance against time graph before?

P

No.

BH

So its completely new?

BH

Yes.

BH

When I asked you to do the test right at the beginning before you'd done any work, how did you feel you'd done on that? Could you do that?

P

We didn't understand it at first - we needed a bit of help from Mr Taylor but then we were alright.

BH

What about if you did that now do you think you would feel confident?

P

Yes.

BH

If you could sum up, what would you say that you had learned in the two weeks? If somebody said you'd spent two weeks doing maths - I want to know what you were learning during that time. Can you tell me - whats the main thing you had learnt?

P

Don't know.

BH

Perhaps, what do you understand more clearly now than you did

P

Don't know.

BH

What would you describe the work as being about.

P

Graphs and time and distance.

BH

So it's about time and distance and things that were moving and it was about graphs showing time against distance. You feel you've got a good idea about that now?

...

What about speed and time? Do you feel if you looked at a graph you would make sense of it?

P

We didn't understand them at first.

BH

Were there any of the graphs that were particularly difficult to make sense of.

P

There were some graphs where you were asked to look at say height against distance. They were more difficult to work out because you had to think about what was what and it wasn't just a normal graph like we were used to drawing. It was different axis. So you had to look closely at the scale of the axis.

BH

I think the birds was one of those wasn't it?

P

Yes.

BH

I think you ended up talking about that - was it height against distance or was it height against time but you seemed to sort that out by looking at the axis. Have you got any other observations or comments about the work or questions to ask me.

P

No.

BH

OK. Thankyou.

BH

I'm interested in finding out, really, what you thought - its not a test or anything. First of all can I ask if you actually enjoyed the activities from when we started with the dice game over the last couple of weeks.

P

Yes. Better than books.

BH

What were the particular aspects which you enjoyed the most.

P

Computer.

BH

Everyone ?

P

Yes

BH

What was it about the computer that made it the best.

BH

Real graphics instead of just drawings of people.

BH

Which system were you on?

P

Both.

BH

So the fact that it was real was important. It was something different from books.

P

... how to get graphs on paper by just looking at pictures.

BH

So that was something about mathematics - getting graphs onto paper. So what do you think you learned when using the multimedia system and the interactive video system.

P

Computer - learning how to use a computer was important. Learning a bit more about graphs - distance and time graphs.

B

Is that something that you knew much about before?

I hadn't done graphs before so that was entirely new. Well I knew about them but I didn't know that you could just get them onto paper by just looking at somebody running or something like that.

BH

Do you feel that you could do that now - if you saw somebody running along, you'd know what the graph say of distance against time would be like?

P

A couple of times like, say, when they stopped without slowing down. If I had a watch or something so I could see what the time was - so you could sketch the graph.

BH

So that was distance against time. What other graphs did you come across.

P

Height against time. Speed against time.

BH

So if I said to you, could you draw me a graph of say the runner running a hundred metres, say, speed against time, would you be able to sketch that for me.

P

Yes.

BH

Can you describe what it would look like?

P

It were like speeding up, then going the same speed for the rest of the distance.

BH

What about at the start.

P

Speed against time - your time would increase - your speed wouldn't go anywhere because you're not moving.

BH

What does that take account of? It was a straight line. Why does that happen?

P

... starts and you're getting ready to start running - reaction time.

So we talked quite a lot about the activities and about multimedia. You were organised into pairs for the game and into groups of three for the multimedia. What did you feel about working in groups?

P

Enjoyed it.

BH

Do you normally work in groups.

P

No. Not really. Just work out of books.

BH

So what would your preference be - would you prefer to work in groups or work individually.

P

When you all work in groups you can all put a bit towards it and get more out of it.

BH

Does it help you to understand more, perhaps, difficult ideas do you think?

P

Yes more people on it. It's like you think of one idea and someone else thinks of it. So that helps.

BH

Overall what do you think you actually learned over the couple of weeks? Can you say what you think you learned - do you now understand better?

P

Graphs. Understand more than before.

BH

Jonathan?

P

Same - graphs really.

BH

Graphs particularly about what - distance and time, height and time?

P

I want to ... going up and down ... just drawn a straight line.

Overall were there any things that you feel the other activities covered which multimedia hadn't covered. Were there any things that you learnt from say working in the books or ... We tended to talk about the computer - were there any other things which you learnt?

P

Graphs don't always start at the bottom corner.

BH

That's right. You did some sections on SMP? We talked about some graphs being linear and some non-linear. So what do we mean by linear graphs?

P

Straight lines.

BH

So what makes a non-linear graph?

P

... curved or ... a different angle.

BH

Most of the ... that you were looking at - how would you describe it - would you say it was linear or non-linear.

P

The graphs - non-linear mostly - curved.

BH

That's fine - is there anything else you want to say about the work that you were doing?

P

No.

BH

OK.

SUMMARY OF TEST RESULTS

The pre-test, post-test and delayed post-test are included in sections (a) to (c) of Appendix 2 (iv). Only questions 1 and 3 were used from each of the papers.

The mean marks out of a total of 15 were as follows:

Pre-test	Post-test	Delayed post-test
7.43	12.48	11.65

Of particular interest are the individual marks of the pupils who are the subject of the video recording, which is reported upon in the following chapter. Their results were as follows:

	Pre-test	Post-test	Delayed post-test
<u>Group 1</u>:			
Laura	12	abs	8
Chantel	12	15	14
Claire	10	14	15
<u>Group 3</u>:			
Philip	8	15	8
Neil	5	8	4
Jonathan	13	11	13
<u>Group 4</u>:			
Joanne	0	11	10
Caroline	0	14	8
Vicki	5	13	9

SUMMARY OF QUESTIONNAIRE RESPONSES

Post-Trial Questionnaire

1. Did you enjoy working on the activities about graphs ?

YES	NO
28	**1**

Use the space below to give reasons for your answer:

A change/different - 11 *Interesting - 6* *Group work - 2*
Read/understand graphs better - 5 *Fun - 3*
Computer - 3 *Not text books - 3*

2. How much did you like working in groups ?

Very much	Quite a lot	OK	Not much	Not at all
12	**11**	**4**	**1**	**0**

Use the space below to give reasons for your answer:

Discuss things - 12 *Exchange/share ideas - 5*
Better results - 4 *Can help each other - 5*
Fun - 2

3. How much did you enjoy using the multimedia system ?

Very much	Quite a lot	OK	Not much	Not at all
21	**4**	**2**	**1**	**0**

Use the space to give your reasons:

Novel - 9 *Interesting - 2* *Helps you to learn - 2*
Good for explaining how graphs work - 1
Graphics - 3 *Too easy - 1*
Fun - 1 *Like computer - 1* *Sound - 1*
Video sequences - 1
Allowed to choose anything you wanted to do - 1

4. (i) What do you think you learned whilst using the multimedia system?

How to understand/read graphs - 6
Why and how of graphs -1
What graphs really mean/you could see it all in action - 1

(ii) Did the multimedia system help you to understand anything better?

If so can you say how?

Graphs - 6
Video provided clearer explanation (than text) - 2
Why graphs don't always start at (0,0) - 1

5. What do you think you learned overall during the activities about graphs? Say what you think you understand better if possible.

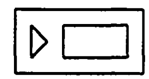
The way graphs work - 2
More about distance vs time graphs - 1
How to draw graphs better - 1

CYCLE 3 VIDEO TAPE TRANSCRIPTS

CONTENTS

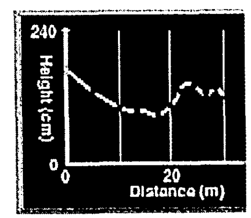
Group (1): Laura, Chantel, Claire (0hour 37 min 52 secs)	Context notes
Episode 1: Start (0 hour 00 min 00 secs)	Cheetah playing - loud background noise Feedback from "cheetah" sequence - correct graph choice for distance against time.
L. Mmm, so we'll just go through 'em	Pointing to the screen.
L. Long jump	Using the mouse.
Ch. Yeh	
L. See what its like. Whaaat!!	Graph of height against time.
Cl. Yeh they're right them aren't they?	
L. No	
Ch. It's OK.	Reassuring Claire that "It's OK".
L. We'll just try them Test.	'Testing' for feedback on choice of graph. - Computer provides feedback to 'try again'.
L. Try it again! Right test for it now Go back to	Pointing to the screen and choice of new set of axes.
Ch. Try that	
L. It's not that one.	Feedback from computer confirms that it was not the correct choice.
	Teacher intervention, identifying individuals for purpose of video - attempting to clarify the task.

Episode 2: Uncertainty about the task (0h 01m 39 s)

L Just play it.	Viewing the various sequences.
Cl. You can play them big an' all.	
Ch. Just stop it Laura! Info. Pole vault Put it on big screen.	'Stop' referring to the video sequence. 'Information' option on the menu bar.
L. You can't	
Cl. You can. That one there. That one with play.	Pointing to the appropriate option on the menu bar. 
L Oh that	Also pointing to the option indicated by Claire.
Cl. Yeh that	
Ch. How did you do that? (Laughs)	Screen momentarily blanks before running the sequence on the full screen.
BH Whilst you're watching the video you might think about what the graph of distance against time might look like.	
Ch. Is it just meant to be distance?	Viewing the 'Birds' sequence at the same time as this exchange is going on.
BH. Well we can start with distance against time and then what you'll find is you've got the choices like speed and some of them give you the option of height against time.	

Episode 3: Clarifying the task

	Viewing aeroplane sequence.
Cl. Here, which one?	Clearing the selection on the computer menu.
L. The pole vault were a good one.	
Ch. .... birds.	
Cl. Yeh do 'Birds'.	
L. Just let me ...... oh	Pointing to the screen .... screen moves on.
Cl. It's right weird though isn't it?	Referring to the graphs for the birds video sequence.
BH OK. So you've got two choices. Let me just show you. You got your choices on that axis. You're on distance against time but it could be height against time or it could be height against distance so we'll go back to distance against time because that's what we're interested in .... OK now here you've got the choices, so is it that, OK? or is it that one? or is it that one'? In fact what you might do is before you actually look at these graphs is that you might just think about what you think, and sketch the graph and then compare it with the choices that you've got. OK?	BH making reference to the appropriate screen controls during the explanation of the task.
Ch. Should we watch now.?	Pupils now sketch their own graphs.
(Muffled sound reproduction)	
BH. Have you got some ideas?	

BH. So you think it's going to look like that?	
Cl. It starts off in the air ..... doesn't it?	
Ch. Yeh	
BH. So go on, say why you think it's the shape it is.	
L. Well it starts off in the air. So it's not like starting from the beginning of the ...... (unclear) not going up and coming back down.	(Referring to the origin as the "beginning" of the graph).
BH Right	
L And it bounces as well. It bounces a bit there.	Referring to the sketch.
BH. Right. So if it's here, are you saying it is up in the air?	
Ch. Yeh. Because it started off up here	Pointing up in the air at the same time. 
BH Right. Now is that a measure of distance or is it of something else?	
Ch. The height	
L. Yeh. It's the height isn't it? Yeh that's the height if it's up there.	
Cl. Oh yeh.	
Ch. It'll be like that, won't it?	Sketching the graph.

L. The other way.

Ch. Like that

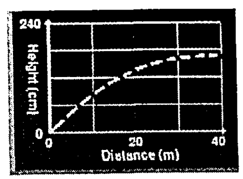
L. Yeh

BH So tell me what's going on there now

Ch. Well its starting from here, you can see it flying, its travelling a further distance.

BH. Right
So that's similar to the one you looked at before, isn't it?
OK. Do you want to see if you can select one that's close to that?

L. That one



pointing to the graph on the screen.

BH. OK

L Should I test it

BH Test it. Yes

L. Oh, yes!

Sitting back.

BH. OK. So do you want to let it run automatically?
BH. You can see the distance being mapped out.

Full screen video with graph overlay on the motion.

Episode 4: Height against time (0h 10m 23s)

BH. OK. So what would be interesting how would be to think about what <u>does</u> height against time look like. That's really the graph that you sketched isn't it.

Ch. Yeh

BH Is that an option? See if you can find it down in that box.

L. This one?

Pointing to the screen.

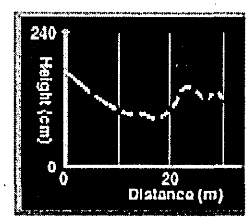
BH. Yes. You've got height against time

L. Yeh

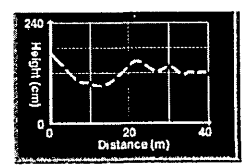
BH Then in the right hand box see if you can find something close to what you had.

[L. That
[Ch. That
[Cl. No, keep going

L. It might be that one.



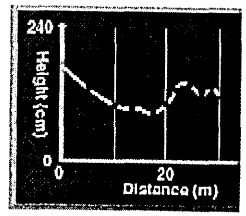
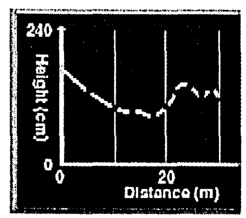
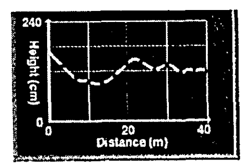
as opposed to



BH. So why do you think that one and why not the other one?

Ch. Well it's not flied that far ....

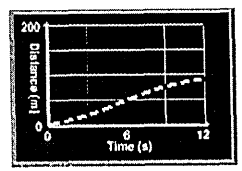
L . It's, mmm, ... well it like goes down and back up and then stands up.

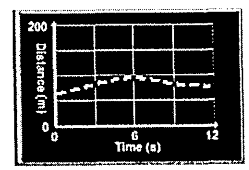
L. I can't (unclear) ..... because that one stands there doesn't it.	(pointing to the origin).
Ch. And he sails higher up. And it can't .... (?)	Pointing to y axis pointing to here
BH It starts higher? So what's happening here?	
L What is it jumps a bit back up again and jumps again	
BH Right. OK. Do you want to test that then?	
BH Right. OK. Let's try gain What do you think the other one might be?	Feedback from computer to try again.
L That?	Uncertain.
BH So you think it might be that one? So if it's that one why isn't the other one. What's the difference between the two?	
L Oh! Oh! That one stopped before the end of the telly and that one's gone on	 
Cl. Shall I try that?	Jumping out of seat and pointing excitedly at the screen.
L. Yeh.	
BH. OK. So what do you think that other graph was showing then? That other one .... if you want to flick back to it.	Full screen replay.

Ch.	Well it's showing them taking off	Pointing to the screen.
BH	What do you think the axes could be? Just flick back through on that one.	
L.	This one?	
BH	See what else you've got to choose from	
L.	Distance-time	
BH	Done that	
L	Height against distance	
BH	Height against distance? So what's happening as the distance is increasing, what's happening to the height?	
L & Cl	It's getting lower.	
L	Yeh	
BH	Right	
BH	OK. Do you want to switch around the terms of who uses the keyboard? That might be a good idea as well	
Cl	Ah - I got to sit on the end again!	Claire refers to having to sit at the end again.
Ch	Do you do another one?	Looking to BH.
BH	Yes, choose another one.	

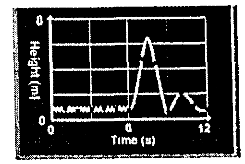
Episode 5: Cheetah. (0h 14m 16s)

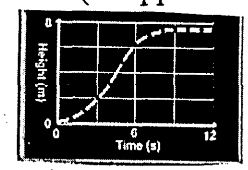
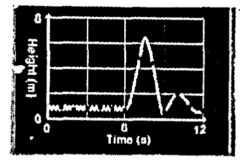
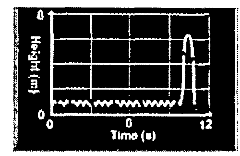
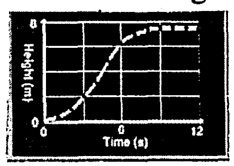
		(Laura to Chantel).
L.	Do one that you want, cos like, well I did one	
Ch.	Do cheetahs. What do you two want?	
Cl.	Cheetahs.	
Ch.	Great. Play it.	
Cl.	Oh, speed against time	
[Ch.	Play it.	
[Cl.	Play it.	Bottom left hand corner.
Ch.	Should we start on there? When its cleared. Distance?	
Cl.	Is it distance against time we're doing?	Sketching graphs.
Ch.	Yeh, distance against time	Pointing to the origin
L.	So it's starting off no distance and time.	
[Ch.	It goes - it gets faster	
[L.	That's right	
[Ch.	It'll go up like that, won't it?	
Cl.	Try that.	(Claire active-drawing graph - not very active in discussion). 'Correct' feedback from computer - full screen with graph overlay played.



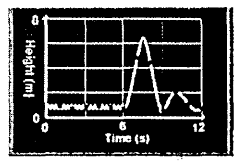
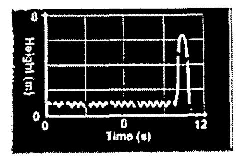
L.	Speed against time	
Ch.	Speed against time	
L.	So speed	
Ch.	It'll go up again won't it? Like that	Showing sketch to the others.
Ch.	No! No! No! No! No!!	Mistake made in sketching graph - speaking to herself
L.	That were it	
Ch.	Well he'd already started off speeding - hadn't he! He was slowing down wasn't he? Like that	
Ch.	Aye like that!	Selected graph 
L.	Yeh, test it	
Ch.	Or that one	
L.	Test that one!	Back to option above - sounds certain!
Ch.	He were already running, weren't he?	
L.	Yes!	Switched places and Claire took centre position and control of the mouse.
I.	Which one are we going to try now?	
Cl.	What do you want to do?	
L.	What about pole vault?	
Cl.	Yeh.	

Episode 6: Pole vault (0h 18m 30s)

Ch:	He's travelling - up isn't he?	Graph on screen 
Ch:	And he gets faster. So it's not that	
Cl:	So it ... mm ... it would go up wouldn't it and it would drop down like that?	Showing sketch to Chantel
Ch:	Yeh	
:	Unclear	
Ch:	It would go up and just across .... a bit slanted a bit.	Taking turns to complete each others statements
L:	No! No! but No! but because its .... look it's distance against time right? He's running first, isn't he?	
Cl:	Yes, and he's still travelling when he pole vaults.	
L:	Yeh but he's going, he's going	
Cl:	Slower!	
Ch:	He's not going a right long distance is he?	
L:	No.	
Cl:	Yeh it'll go like that.	Sketching a graph.

L:	No, go through the graphs	Pointing Claire to the right hand box (as opposed to the left hand one - choice of axes) 
Cl:	Yeh that	
L:	No not that one	
Cl:	Oh it could be that yeh.	
L:	No not that one	Similar to above.
Cl:	How do you ....?	
L:	Because he's going across there isn't he?	Pointing to the graph - graph changes to  again.
Ch:	That! that one I think	
L:	Yeh. Test that one!	
L:	Yes!	
Cl:	What other	
Ch:	Check the other graphs	
Cl:	Height against time	
L:	No - do that one. Height against distance.	
Ch:	It'll be that. He'll travel there and then he'll go right up and stop like there. It'll be a line and then a straight up	

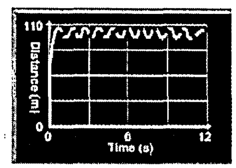
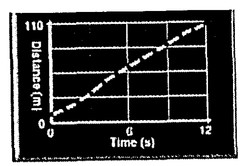
Cl:	Yeh it'll be a flat line, won't it? A flat line.	Sketching the graphs.
Ch:	It goes right up and then just steps.	
Cl:	It comes down	
L:	No	
Ch:	Yeh! That's the height	Emphatically nodding her head.
L:	Oh yeh! yeh! yeh!	
L:	But it might be a bit .... (unclear)	Correct choice made and video sequence run.
Cl:	A bit .... (unclear)	
Ch:	Try height against time.	
L:	(Points to the screen)	
Ch:	Yeh do that. So we've got to do a graph	
L:	Height against time.	
Cl:	So what am I going to do now?	
L:	Draw a graph	
Ch:	Height against time. The time it takes, isn't it?	
unclear		
Ch:	I think it'll be like that.	Showing sketch of graph to Claire.

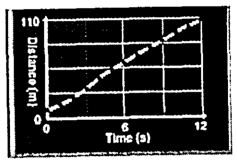
Cl:	Yeh	
		Claire about to test for feedback from system.
L:	Wait! Wait! wait! wait! It'll be thin, won't it? Because it didn't take long for him to jump up. It won't be as wide as that.	Pointing to Claire's graph.
Ch:	I think it will be like this	Showing Laura her sketch.
Cl:	?	
Ch:	It'll go along a bit more than that though. But	Leaning over to Laura.
Ch:	That yeh	 in contrast to 
L:	That one	
Cl:	Great	'Correct' feedback from computer.
L:	Is there another graph?	
Ch:	No that's it	Switch round so Laura takes centre position.
L:	Right what shall we do next?	
[Ch:	The hurdles	
[L:	The hurdles	Turning to Chantel.
Cl:	Let's do the 100 metres	
L:	Oh the hurdles	
Cl:	Yeh all right	

Episode 7: The hurdles (0:24:50)

		Turning to Chantel.
L:	Right Height against ...... Oh! What are we going to try out first?	
Oh:	?	
L:	OK	Start to sketch graphs.

(Exchanges between Laura and Chantel - not clear)

Cl:	Well he's (it's) going to get smaller when he jumps in the middle, doesn't he?	
Cl:	Well the speed is something like that	
Ch:	It just go up, like that	
Cl:	Yeh Right, try it then	
Cl:	Do you think it'll get to	Pointing to 
Ch:	No. It'll... That one, it's that	
L:	That one?	
Ch:	It is	
L:	That one?	Nodding to 
Ch:	No. The one behind it	
Ch:	That one	
Cl:	That?	
Ch:	You can ...... he's going along the hurdles, isn't he?	Drawing a wave motion in the air.

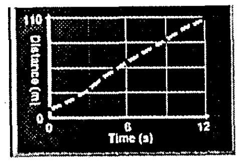
[Ch:	He'll be going at a constant speed along the hurdles	
[L:	Yeh. Yeh. Yeh. that's right	Positive feedback given by the system.
Ch:	Do the journey ...... distance against time	
L:	Yeh	
Ch:	Cos it'll just go up won't it? Like that.	Sketching graphs. (Claire quite excluded).
	Like that	
L:	Yeh	
Ch:	He'll just keep on travelling and going up like	 (on screen)
L:	Like that?	
Ch:	Yeh	Positive feedback from computer system.

L: Do another graph - speed against time

Ch: It'll go up and stay like that

Sketching graphs/close exchangers but not clear

L: Oh yes. Yeh. Yeh.



Quite sure about the graph - did not bother to test it. Switched around to Chantel now at the centre, position

L: Oh that's it.

Ch: Which one haven't we done? Aeroplane?

L: We haven't done aeroplane

Cl: And we haven't done Long Jump

(unclear exchanges)

Episode 8: Aeroplane (0.28.24)

Ch: I'll just play it?

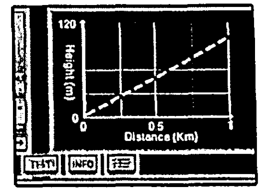
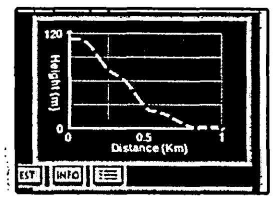
Cl: Yeh

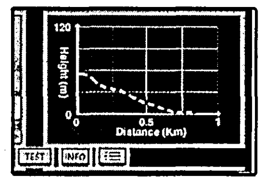
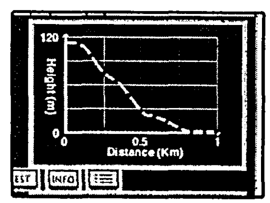
Ch: Distance against time

Watching the sequence of the aeroplane landing

Ch: So it's just going to go up
So it'll just go straight
Well it might not ....

Sketching her graph

Cl:	Is that it?	Pointing to graph on screen 
Ch:	It doesn't go back or anything? -	
Cl:	No it just keeps going. So	
Ch:	Let's see what'll happen	Choosing to test out the current graph about which they are not certain. Wanting to wait
L:	No. No. No.	Correct choice made - but no-one appears to be sure why.
Ch:	Now its height and	
BH:	So what's going to happen to the height as the time passes	Sketching the path of the graph in the air 
Ch:	It's getting lower, isn't it? (30.31) It starts	
BH:	What's it going to end up as?	
[Ch:	Down there	
[L:	Down the bottom	
Ch:	Like that	Referring to sketch
Ch:	So what have got? Height against distance	Referring to choice of axes

BH.	What do you think Claire?	
Cl:	Mmm	
.		
.		
.		
.		
[Cl:	It'll start off high and er end up at the bottom	
BH:	Right	
BH:	OK. See if you can find a suitable graph	
Ch:	That one?	To Claire 
Cl:	Yeh	Chantel also checked with Laura who nodded her agreement.
L:	Doing height against time?	Positive feedback from the computer.
Ch:	Yeh It might just be the same	
Ch:	But	Looking first at her sketch, then at Laura's and then at Laura herself for a response. (Clearly uncertain).
L:	Like that	Showing her sketch to Chantel.
Ch:	Yeh	
L:	Go through them	
Ch:	Yes that one	
Cl:	That one.	Confirming Chantel's choice after she has cycled through the others and back again.

Episode 9: Long Jump (0.33.23)

Switched round for Claire now to take the centre position.

Cl: Which one do you want to do then?

[Ch: Just do the long jump
Cl: The long jump
Ch: That's the only one we haven't done

L: Which graph are we on

Cl: Distance against time

Ch: Right. Right. She runs, doesn't she?

Sketching of graphs

Cl: Yeh

Ch: And I bet one stays I mean at that speed
And then she jumps

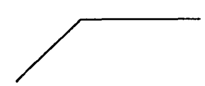
Cl: Which height?

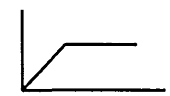
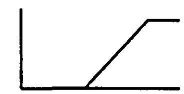
Ch: No so that means she stops, doesn't it?

[[L: But it's not distance it's not height
It's distance it's not height
[Cl: It goes erm ......
[Ch: It goes up
[Cl: It doesn't go ....

Correcting what she meant to say

Ch: Then it goes at .... speed.

Mapping out  with her hand.

Cl:	Shall I try it	
Ch:	And then stops like that	Showing sketch of 
Ch:	That!	Pointing to the screen and resketching her own version (seems sure) 
Cl:	That? Try it?	Correction response given from the system and the motion is played with graph overlay. It is watched especially closely by Chantel who maps out the graph with her hand. Pointing to section where the distance is shown to be constant.
Ch:	See the	
Ch:	Right	
Cl:	Shall we do height?	
Cl:	Height against distance	Sketching the graphs
Ch:	Height against distance	
Ch:	So it'll just ..... whatever height she's doing ...	
[Cl:	It'll be like that	All looking at Claire's sketch
[Ch:	Go up and down	
[Ch:	Then she'll just go jumping like that	Showing her sketch to the other two
Cl:	And she lands ... like that	
L:	And then jumps up again	
[Cl:	Yeh like that	
Ch:	And then lands again doesn't she?	

L: That!
Oh! No! No! No!

Cl: That
That cos she .....
Ch: Yeh that ...
Cl: ... she don't run at first

L: No! No! No!
.
.
.
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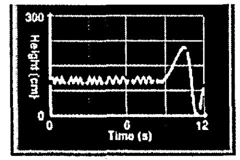

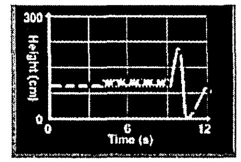

Incorrect feedback given
(unclear exchanges)

Correct response chosen but reasons why it was one rather than another not discussed due to the lesson ending.

Group (2): Mathew, Ryan, Philips. (0.38.28)

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Episode (1) Cheetah (0.41.26)

LD: Right. You've just looked at Cheetah have you?

R: Yeh

LD: Yeh

R: So we want to know which graph it is.

P: Mmm

LD: Now then, what are your axes going to be?

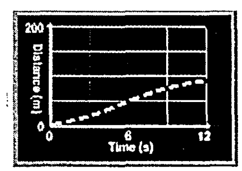
R: Mmm. Distance - time

LD: Distance-time? Hmm! Hmm!

R: Yeh

M: We've done another

Looking at the graph on the screen.



R: Well it starts off from stop doesn't it?

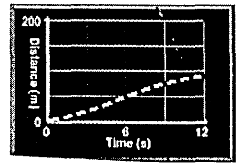
LD: It starts off from sl ....
R: Slow
LD: Right
R: I think
LD: It starts off slow and speeds upDoes it

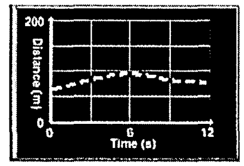
(Ryan responds by saying what he thinks LD was going to say?)

P: It depends. Does it start off slowly or what?

M: It's running isn't it

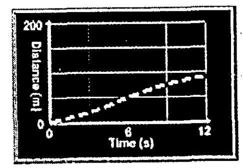
LD: Yes it's already running

R: It's already running, so it's not going to be that one — Pointing to 

P: It's not this one is it? It's that other one — Referring to 

LD: Is it already running?

[P: No
R: No
LD: No it's not, is it

[P: So it's like just speeding up. That one — Nodding to
R: That one — Pointing to the screen 

[LD: So it starts from a standing start, doesn't it
P: And then it's ....
LD: So it's distance is going to be what when it first sets off

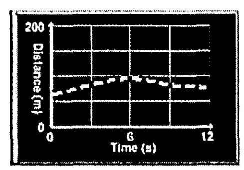
R: Zero

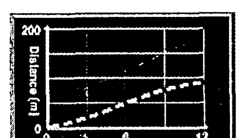
LD: Right. And it's time is going to be?

R: Zero

[LD: So it's going to go through nought - nought isn't itOK
R: Yeh

[LD: Now then is it going to be speeding upM:
M: Yeh
LD: Or does it start off quickly and slow down

P: No it gets faster — Pointing to 

R: It can't be that anyway. Because ..... It's that one. — Pointing to 

LD: You think it's that one?

R: Yeh

LD: If you think it's that one, then you can test it
Test to see if that works

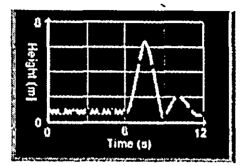
[R: Well done!
[P: Well we're brilliant! — Waving their hands in the air.

Episode (2) Pole vault (0.43.12)

R: Pick another one

P: Er. Pole vault

R: Play. Just play it — Talking to Matthew



R: It could be that one see
He moves along and then he jumps up and then
he bounces — Pointing to the graph
Tracing the graph out in mid air.

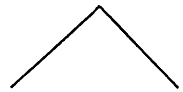
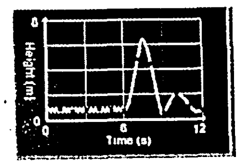
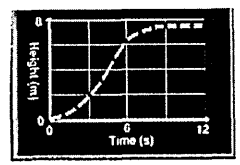
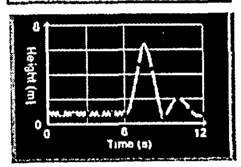
LD: Why can't it be that one?

R: It <u>can</u> be that one

LD: It <u>could</u> be that one?

[R: Although .... it doesn't start
[M: No look at the start — Both pointing to the starting section of the graph at the same time.

R: But it depends on the height. Is it on the bottom of his feet or
his head?

LD:	Right. Yeh. Good So if it's counting from the top of his head, say .....? On there what happens?	
R:	He runs up	
LD:	He runs up and over the post	
P:	Yeh and then he bounces on the mat	Mapping out  in the air. Bell for the end of the lesson rings.
LD:	Does he bounce on the mat	
R:	No he doesn't. He doesn't	Emphatically shaking his head
P:	Er. Er. Er. Can we go?	Talking to Ryan
R:	You've clicked on that about twelve times haven't you?	Talking to Matthew
M:	He gets straight up. He gets up	They all point at the screen
P:	Yeh	
R:	Yeh but that's where he's standing up - he doesn't jump up that high does he	Referring by pointing to the difference in height between the starting and finishing sections of the graph 
P:	Yes, but he's stood on the mat isn't he? He's stood on the mat so that's going to add to it.	
R:	Well it's not that one	
P:	It's not that one	Referring to 
M:	Not that one	
R:	No. So click on test	
P:	Cos he's on .... Yeh!	Referring to 
LD:	OK	
P:	See! Hah!	Slapping Ryan on the back!
LD:	Well done	

Group (3) Philip B, Neil and Jonathan (0.45.00)

Episode 1. Setting up and clarifying the task

BH: It could be that one. OK?

BH: Or that one

N: It's that one

BH: Right why do you think it's that one?

N: Because she's slowing down and speeding up to the step

P: Because she starts off slow to start with and she doesn't really go anywhere while the time is moving.

[BH: What's happening to distance over time
J: Is she ..... the reaction rate

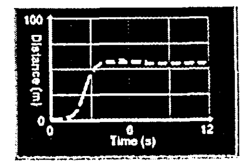
BH: Oh, right. You said something about reaction rates ..... where ......

J: At the beginning

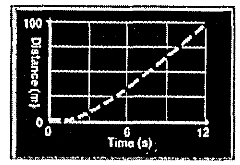
BH: At the beginning?

The task was outlined initially by BH - they were asked to select a video sequence, think about what the graph of distance against time might look like, sketch it, discuss their ideas and then use the system to test these out.

In outlining the task in the context of the 100m: Referring to



Referring to



Pointing to the initial section when referring to 'slowing down' and the remaining section to show how she is 'speeding up'.

(The concept of time 'moving' - an example of the language used clashing with another example of 'movement' i.e. of the athlete.)

Talking to Jonathan.

J: That's why she isn't going anywhere

BH: Right. That's why it's flat. OK.

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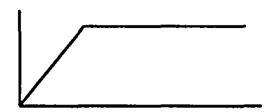
BH: Right so what does speed against time look like
What do you think it's going to look like

J: It goes like that

BH: What happens at the top

Mapping out the shape in the air



BH: OK. So why does it go like that?

P: Cos she reaches a top speed and then she keeps at that speed until then end.

BH: OK Good. Right.

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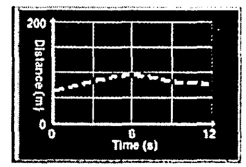
Further explanation from BH regarding the task. Answering of technical questions regarding the use of the software - mainly from Neil.

Episode (2) Cheetah. (0.49.15)

P:	It starts off slow	
N:	It starts off slow, gets really fast and then it	
P:	It stops	Neil laughs (at them speaking simultaneously?)
N:	.... stops	
N:	That'll be what it's like	
J:	What?	
N:	See what it'll be like	Jonathan leans over to Neil. 
P:	Yeh. That's what it's like there. Wait Check the other one Neil Go on to the arrow	Pointing to the screen Pointing to the 'arrow' on screen (for Jonathan).
J:	This one?	
P:	No. Yeh	
N:	It slows down for its pounce. Like that	Showing graph to Philip.
P:	Yeh like that	
N:	It's my view Ah. I got it right didn't I. (Laughs)	Looking at Jonathan.
J:	You've got to put distance against time as well	
P:	Aye. So. Like that? Think?	Showing graph to Jonathan

N:	It's not bad that ...... ish	Confirming Philip's attempt.
P:	How do you spell Cheetah?	
[N:	C H E T A (laughs)	
J:	C H double E T A H	Further clarification from BH on use of the software - specifically on how to select a different choice of axes i.e. distance against time. Also clarification of the testing (feedback) procedure which they seemed to have forgotten how to put into effect.
	(0.51.20)	
BH:	So what do you think the graph would look like? We're talking about distance against time for this cheetah.	
[J:	It's going to go up like that	Jonathan sketches it out in the air.
N:	Well its ... distance. Distance there	
H:	Distance against time. Yes	
N:	Distance is .... It goes up the distance, doesn't it? Well like along. Time	Uses the term "goes-up" to mean "increases"? or "goes up" on the graph?
BH:	What's happening to the distance covered?	
P:	It's getting greater	
N:	It's going up. Higher	
BH:	Well what's that going to look like?	
N:	That. It gets ...	
BH:	Do you want to sketch it?	
N:	That. It like goes and then slows down	
BH:	Right. So why does it do that?	Pointing to Neil's graph.

N: Cos it's running like and it sees it's stag and then it like slows down and then it runs and tries to pounce on it.

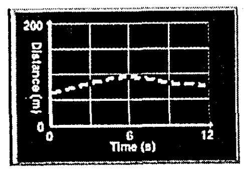
BH: Right. Right. So there's a difference ... it's speeding up and slowing down a bit. OK?
Do you agree Jonathan?

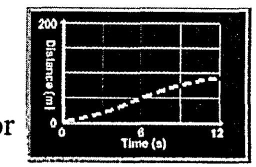
J: ......

Showing his graph.

BH: You think it's more of a straight line?
What about Philip?
Right. OK.
So what you can now do is click on there
See is it that one?
Or is it that one?

Philip shows his graph.

(1st) 

or 

(2nd)

P: That's more like the one I've got. The second one.

BH: Right. So we've got that one ...

[P: Yeh
[J: Yes

BH: So now you can test it
OK. Do you want to test it?

N: Well done!

BH: It'll run it through now for you

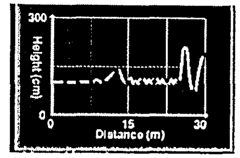
P: It's there

N: Aye it sees its' stag doesn't it

Philip appears to point to the section at which the graph flattens out during the full screen replay with graph overlay.

Episode (3) High Jump (0.53.34)

P:	Go on pick what you want	To Jonathan (in control of the mouse)
N:	Plane. Not had a look at that one. Aeroplane	
J:	I thought I could choose what I want	
N:	O Yeh. I'm sorry. Of course you can	
N:	High jump	
P:	Doing height against time still?	
N:	Height against time?	
P:	She starts off slow	
N:	She has to start height, time, height	(N looks puzzled)
J:	She starts like that	Making a wave motion in the air.
N:	She goes like	
J:	Because she ...... like that	Looking at his sketch.
N:	Like that. That's what I'd say	
J:	Yeh but she go like that when she's running	Making the wave motion again.
P:	Yeh but then it'll go down again won't it?	
N:	(Laughs)	
P:	Yeh .... try the other one	Pointing to the screen.

N:	What's that? Speed against time?		
P:	No I mean the other thing		
N:	Height against time? What's that?	Philip leans right over and takes control of the mouse whilst Jonathan is busy sketching.	
J:	That's height against time. That's it!		
N:	That	Looking at the graph 	
J:	That's it. That is it! Yeh!		
P:	Yeh. She runs along		
J:	She runs and she goes like that	Making the wave motion in the air	High level of collaborative talk-quite excitedly (0.54.58)
P:	She jumps. She falls and then she stands up again does not she	Pointing at the screen	
N:	What's that for then?		
J:	Look. Right	Neil points to first small lump in the graph	
N:	Just play it again. Have a look		
J:	No. She'll set of. She runs like that. Then she does a jump. Then she starts going like that (bouncing) and then she		
N:	Why does she do a jump?		
J:	Play it!		
P:	Test! Test! See		
J:	Watch!		
N:	Let us have a look at this		
N:	Oh alright well she stands up again so that can go like that.	Referring to his own sketch.	

P: Look

N: Let's see her do her little <u>jump</u>!

P: She starts off running. Look there!
N: Oh! I thought ....
P: She runs along. Jumps up
J: Aargh!
N: I thought it was from when she starts to move
Eh up!

N: I thought that when she starts to move she does a little hop and then carries on moving (tracing the path out on the blank screen)
J: Rubbish. Told you!
(All laugh)

LD: Why does the graph then never start from (0,0)?

N: Cos it like always ....

J: Cos she's always at that height. She's on the ground
LD: Right. So where do you think they are measuring the graph from then?
Where it says the height in centimetres. It's always above nought isn't it?

N: The height of her head
LD: Right. From her head
And what's the height. Yes. And what is the highest point she reaches?

N: Over the pole. Just over the stick

LD: Right. which is what roughly on the ground?

N: Is that centimetres?

LD: Yes they are centimetres.

N: 30 centimetres. Yeh No.200 No
J: 150 ... 175 ... 160 ... 170

LD: What does each block go up in?
N: 75. No?
LD: 75?
N: Could do
LD: Would you be right with 75
N: Yeh

LD: 75. 150. Yeh 225 and a 300
N: Yeh!
J: Yeh!

LD: So in centimetres how high has she reached?
N: About 260
P: About 220
N: 260!
LD: If that for example ... that's 150, isn't it that line, that line's going to be what?

..

Further period of quite directed questioning by LD.

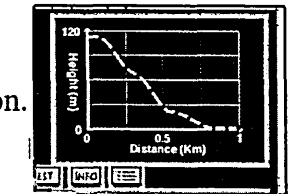
.
N: Right then so she does a little hop there then!
N: Are you going to do plane:
P: What
N: What are you going to do now:
P: Yeh! OK

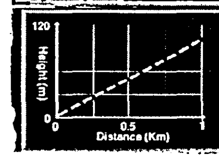
Episode (4) Aeroplane (0.58.18)

N:	Aeroplane	Philip takes control of the mouse.
J:	It's boring that...	
N:	But I want to see this	
J:	....	
		Watching the video.
N:	Do they speed up when they hit the ground - <u>planes</u>?	
LD:	No	
N:	Oh it's height against time, isn't it?	
J:	Oh great. We didn't do that for the high jump?	
N:	We'll have to go back to that then	
P:	No but it was height wasn't it	
J:	Yes but isn't there two?	
[P:	There's speed ...	
[N:	There's speed against time	
P:	It doesn't start off ... Watch this. Height against time	Philip runs the video.
N:	Speed against time that	
P:	Yes but no. We've got to choose which height against time is the right one.	Axes set on height against time. Philip trying to clarify the <u>task</u>.

J: Let's have a look

N: Yah!
Oh. How come it does all the wavy lines?
It goes straight down
It doesn't go up and down does it

Making a diagonal downward <u>wave like</u> motion. 

Making a diagonal downward <u>smooth</u> motion  (1)

[J: Well change it! have a look .....
[P: No but the nose goes up doesn't it

Looking at second option (2)

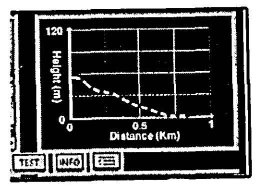
[N: No! That's not it
[J: That's not it

← comment entirely unrelated to video of the plane <u>landing</u>

N: It's taking off that isn't it!

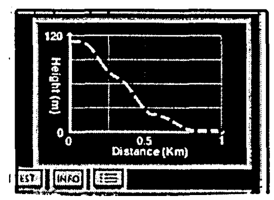
J: That's got to be it

N: Let's just see what it's height will be in metres.
So it will be about 30 metres then

Referring to:  (3) Different <u>scale</u> to (1)

J: Yeh.

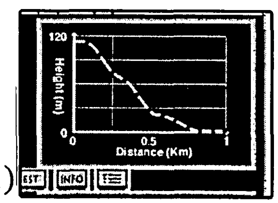
[N: It looks more than 30 metres that
That's more like it.
[J: That's not it

 (1)

N: How many seconds is it?

J: Wait. Wait.

N: Twelve?
That's .... Time it. That's the only way you can do it, isn't it?

Referring to (1) 

P: Look that's it isn't it

N: I'd say it was

J: Yeh OK

P: Right

N: Test?

P: Test

N: .... — Correct feedback from computer system.

P: It's that where it goes up when the back wheels hit the floor

N: Oh it went up

N: Speed against time

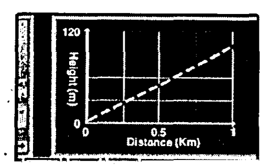
J: What's now, speed against time?

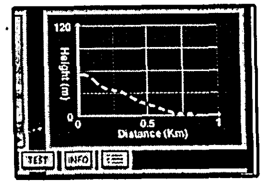
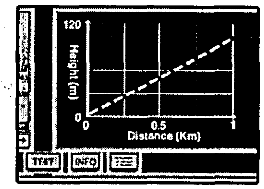
P: ....
No it's distance against time now

N: Is it?
J: Do you want to change that one? — Referring to choice of axes
P: Yeh I've done that. It's distance against time now
N: Distance is going down? No how could it be going down distance? Oh it's just landed.
But it's times going up — 1.00.41

P: What
J: the distanceIt can't .... can't ....
N: .... go down. It just goes up
P: I know it can't
N: So why does it look like that then

Looking at the graph on screen
The whole group is now confused.



P:	Cos it starts from the bottom and it goes up	'It' referring to the graphical representation?
J:	Look the distance is there	Pointing to mid-air 
P:	But that's not it, is it?	
N:	It's not that	Referred to (3)
J:	That is	
N:	No	
P:	It's got to be that	Referring to (2)
J:	That's distance	
P:	Test it	
N:	It is right	
	Because distance goes up and so does time at the same time. Well done ! (Laughs)	Positive feedback given from the system.
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.		
P:	What are we going back to now?	
.		
.		
.		
P:	This is distance against time not height.	
J:	No we're supposed to do another one	
P:	Right this is long jump	
J:	No we've done that one	
P:	No we didn't do height .	BH responding to questions about the technology mainly from Neil, who by this time is getting restless.
J:	We did	
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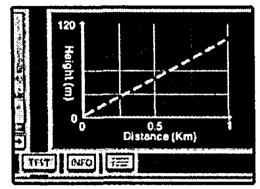
Philip and Jonathan have meanwhile remained on task and selected the correct choice.



N:	Distance going up. Stop
P:	It looks like that
J:	It looks like that

P: She runs .... then she stops the distance

P: Er it's your go

N: My go isn't it. Let's have a look at swans.

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J: Oh: I've done it !
You can thank me. I've just done it

(Making rhythmic sounds in sequence with the movement)

N: Is that ......

Neil and Philip distracted by an examination of Neil's watch.

<u>End of session</u>.

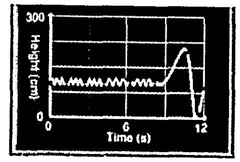
Episode 5 Long Jump (1.09.03)

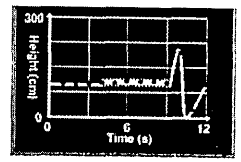
Start of next lession. Group now got up on the interactive video system rather than the CD ROM system about which they were quite critical in terms of picture quality. (Picture quality on video footage poor).

P: No it's the other one

P: It's that one. Cos she doesn't do anything for the first few minutes does she?

Looking at





J: ....

[P: And then she starts running. She jumps. She stands .....
N: Play it with than. Have a look
[P: Test

J: That's her head isn't it? That's her head

Referring to the initial level of the height

P: What ? Yeh!

J: ....

N: Let's have a look. See what it's like

J: See her head's up and down

....

N: That's .... isn't it?
Her head bobs up and down, doesn't it?

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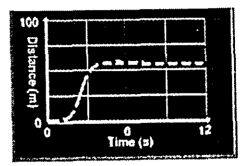
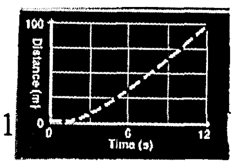
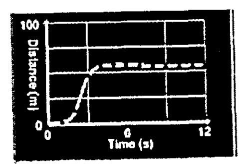
P: Menu

J: What's this one? What's this?
Time against height?

P: Should we try the Cheetah?

N: Yeh

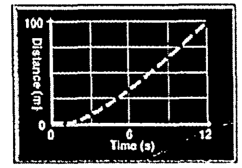
Episode 6: 100 metres (1 hour 12 min 05 secs)

P:	Now do hurdles	
J:	Menu. Can't we do 100 metres?	
P:	Hurdles	
J:	We'll do the 100 metres at the same time Down to view.	
P:	This is the 100 metres.	
J:	100 metres. Wait for the full screen.	
[N:	I know what I think it'll be.	Starts to sketch the graph
[P:	We haven't done this one have we	
J:	No.	All watch the video and sketch graphs
J:	She win. It's Flo Joiner. Florence	Pointing to the screen
N:	That's it. Look.	Showing his sketch 
	This is speed and this is true.	
P:	OK.	
N:	Yeh. Right. Er.	
P:	Distance against time first? Right?	
J:	Yeh.	Referring to 1  gasping at 2 
[P:	That's it. Ohhh! Yeh that's it.	
[J:	No keep going......	
N:	What's that?	
P:	That'll be for height against time. I bet it's that one look. Test it.	Referring to 2 Referring to 1

N: I put it that she slows down like that.

Positive feedback given from the system

Referring to his graph



(Meaning that the race was timed only to the finishing line?)

J: Yeh but they've stopped it there haven't they?

P: We've got that one, yeh?

J: Yeh.

N: What's the other one?

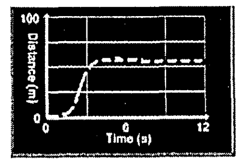
P: Speed.

N: Distance against time?

P: Speed against time.

N: I bet it's that one cost she goes that....

Referring to



J: Yeh it's that.

N: And then she slows down. Well she stays the same speed doesn't she? So.

P: Was that them two then?

.

.

P: Was that them two then?

P: Hurdles!

J: 100 metres. Oh yeh!

P: Yeh

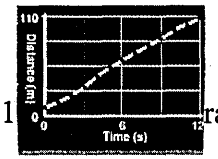
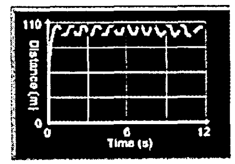
J: Yeh

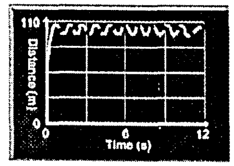
J: It's Colin Jackson

P: Is it?

J: It'll be Ian.......

Episode 7 Hurdles / Vault (1.15.12)

N:	The world record is 12.93.	
J:	That's Jackson. That's Jarrett and that's McCorey.	Pointing to the runners
J:	That was years ago that.	
N:	Oh! It's a new Olympic record! It is.	
J:	That was years ago.....	
P:	So distance against time Distance keeps going up - time as well. So. It's only two choices so its probably that one.	Referring to 1  rather than 2 
J:	So what? Distance against time.	
P:	Are you right?	Positive feedback from the system
J:	It was before Jackson's prime that.	
P:	Yeh.	
J:	He's the best in the world. So he sets off.	
N:	That's what I think it is Speed against time - slows down doesn't he? When he's jumping. He's got to start off again.	Showing his sketch of the graph to the others.
J:	He's.......	
N:	So what have we done now then? What do we need to do?	

J: We need to change it on that arrow.	Pointing to choice of axes option
P: Speed against time.	
P: Yeh.	
J: No.	
P: Heh it's that one cost he jumps over all the hurdles doesn't he.	 Referring to 2
N: That's what I thought	Positive feedback given from the system
	Jonathan nods in agreement
J:	
N: Not a bad guess.	Referring to his own sketch
J: .... the height. Look how tall he is.	
N: It's 10 metres.	Misreading the scale
P: So what have we done now then? What have we done now?	Getting the others back on task
J: What.	
P: What have we done?	
:	
:	
P: How many have we done then? J: What have we done.	
P: We've done long jump, 100 metres, hurdles,	
J: High jump	
P: Cheetah	
P: So there's five left? then?	
J: Mmm	

P: Go on Neil it's your go.
J: Pole vault
N: We've done that.
P: We've done that. We've got birds
J: We haven't. We haven't done pole vault.
P: We've got. We've got left - we've got birds, pole vault ...
J: We haven't done birds and pole vault :
N: We've done pole vault. Oh no we haven't done. High jump! Pole vault! then birds.

Agreeing to do pole vault and then birds.

:

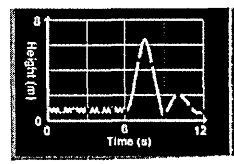
:

Play video sequence.

:

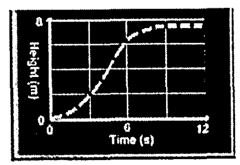
J: What are we doing? Distance against time. It's going to stop at the end. Oh that's not it. That's speed No that's height isn't it No. Wait.

Referring to (1)



N: Yeh.
J: The distance
N: The distance gets higher so it's probably that one is not it No. Wait.

Referring to (2)



Yeh it's that one.

Having flicked through the other two options.

J: But it's got to stop at some time - the distance. Show it on the big screen.
P: Look it's here.
N: He screams as he's falling down
J: Yeh as soon as he gets over.

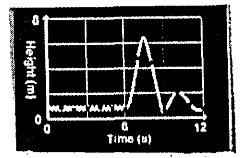
BH informs them that they have 5 mins left.

:

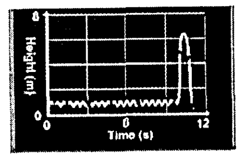
:

P: Height against time
That's it. Do you think?
J: Yeh.
Try it on the other one.
P: Height against time. That's it where he runs along, jumps down, stands up and falls down again. That's it.
J: Or.
P: Or.
J: He runs along, goes up, over
P: I think it's that one.
J: Yeh
N: It's that one I picked.
:
:
P: Birds
It's a load of swans; (1.21.12)
J: There's two.
P: Well two of them.
J: Birds.
N: We'll do height.
J: They're storks.
N: What's the point of this? (laughs)
P: Right so; It starts. What's this? Distance? It's distance is always going higher over time so..... that one.
N: What's that? Distance against height?

Referring to (1)



(1) Philip uses the pointer on screen to trace the graph as he describes the motion.

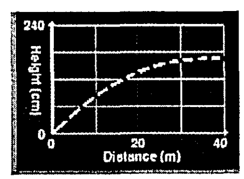


(3)

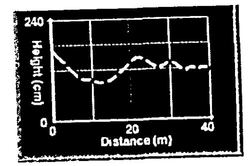
Referring to (1)

Positive feedback - they view the video sequence with the graph overlay with interest.

Referring to (1)

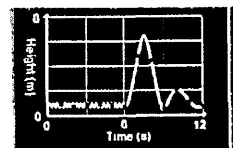
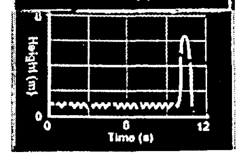
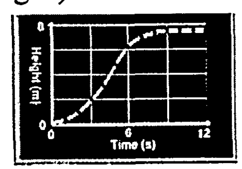


Looking at Jonathan's graph.

J:	Yeh. Distance is	Positive feedback from the system.
P:	So we got that one right. Now it's height against time.	
:		
:		Referring to the graph with the pointer. 
P:	So it comes down and then it jumps back up:	
J:	That's not it.	
P:	It is.	
J:	It can't be.	
P:	It is cos they come down, they land and then they jump back up, until they stop. Watch.	Positive feedback from the system.
N:	I got that before didn't I?	
P:	Right that's it. (12.3.30)	

Group 4 Joanne, Caroline, Vicki

Episode 1: Pole vault (1.28.08)

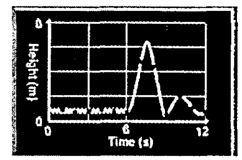
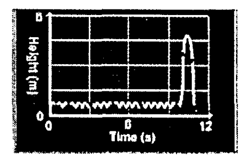
J:	Can we do pole vault? I want to see the pole vault. Right. Do the pole vault.	(Vicki in initial control of the mouse)
:		
:		
:		
J:	And then you go to view	
J:	Sergey Bubka	Pointing to the corner of the screen.
C:	Let's see what the choices are	Vicki flicks through the options.
J:	It might be that one	Referring to (1) 
C:	Or that one	Referring to (2) 
V:	No! Wait! No! It's distance	
C:	I think its that one. Or the other one	Referring to (2) (They have not clearly agreed on the choice of axes at this stage?)
J:	I don't think it's that one	Referring to (3) 
V:	She doesn't know though, cos like he'll be running won't he?	
J:	No! but he doesn't go down. Does he?	

V:	No	Referring to (1)
	So it's either . . . . no, no not on that one.	
	The first one (he) did.	
C:	That's really . . . He runs	Pointing to the screen and mapping out graph (2)
V:	It's either (Click again) that one or the next one	
V:	It think it might be that one	
	I'm not sure though	Referring to (1).
C:	Cost that's when he runs and he goes . . .	Tracing out the last section of graph (1).
V:	Yeh. But. He might	Sketching their own graphs.
C:	Test	
J:	Put it on full screen testing	They are unable to run the 'test' procedure and don't get any feedback.
C:	Press "Play".	
J:	I know but it's got to show it, hasn't it?	
C:	We want to test it	
J:	Press "test" and go along	
	Just press "test" and go along	
C:	Incorrect. Try again	
J:	Oh! Yeh!	
J:	That's why. It must be that one then!	Referring to (2)
	I'd laugh if it was that other one	
	Vicki what are you going?	
	Press "test" then "play".	
V:	Full screen?	Looking at "Help card".
	It's that one isn't it?	
C:	Full screen. Yeh! Yeh!	Positive feedback given from the system but they seem unaware that their choice of axes are distance and time.
J:	Then you want	

J: Play the small screen again
V: We'll have to change. This is wrong isn't it?
It didn't show up . . . .
J: Put it to that one . . . . . and let's see what it was. They consult the Help Card.

J: Sir, we're stuck
We can't get the graph to plot on it.
C: We can't get it to plot what it's showing on the screen
SH: What are we doing? What sport are we doing?
J: Pole vault
SH: Pole vault. Right.
C: We're wanting it to plot the graph while it's playing.
SH: And we are plotting distance against time?
Right?
J: Yeh
V: Yeh
C: Yeh
SH: So let's go through the graphs.
Right
Let's look at the next one then.
And you can't find one of those?
:
:
:

SH:	Why don't we try changing this one here?	
	Try that.	Pointing to the bottom left hand corner of the screen.
	Change let's see what will happen.	
	Right. Height against distance.	
	Right!	
V:	(attempting to ask a question)	
ST:	Woh! Woh! Woh!	
	Let's consider what's happening here.	
	When the man does the pole vault, right?	
	He runs along the runway ...	
J:	That's what we've done already.	
ST:	Yes?	
C:	Then he jumps.	
J:	He jumps, goes up, comes down ...	
ST:	Up in the air. Lands on that big floppy cushion ...	

J:	And rolls off it ...	
ST:	... and bounces back up again.	
J:	That's what we thought.	
C:	That's what we thought.	
ST:	So try that one.	Pointing to graph option 1. 
J	But we couldn't get it to plot ... probably because of that.	
ST:	Incorrect combination? So let's have a look at the next one then. Try that one then.	Referring to the message "Incorrect combination" on screen. Pointing to graph option 2. 
ST:	Right. So change ... erm ... then after you've marked that ... change your ... erm ... axes and then we'll do it again. OK?	Correct feedback from the system. Pointing to the bottom left hand corner of the screen.
C:	Yeh.	All sketching graph from the screen.

Episode 2: Hurdles (1.34.40)

V: What should we do?

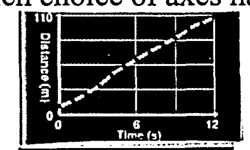
J: Do . . . . Hurdles

C: Full screen. We can watch it first.

(Again they have not been clear about which choice of axes has been made.)

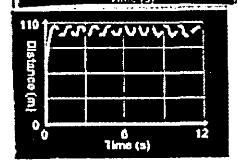
C: Right. Go back to the small screen
Let's have a look at the choices

referring to (1)



J: It's not that one.

referring to (2)



J: It's that one. It's that one

C: Is it distance against time?

First attempt to clarify the parameters.

J: Yeh. Just check that.

Sounds very uncertain. She could check the axes herself - does not seem to be aware of this.

V: Speed against time

J: Speed

C: Speed

C: Just try and plot it with distance

Very uncertain about how to change the axes - they consult the Help Cards.

J: What are we doing? Just trying? Just trying?

J: Test.

V: Should I go on full screen?

C: Yeh if you like.

J: You can't have that . . . . we haven't got the graph on now.

In fact they did have the graph overlay running but did not seem aware of it. Also they had chosen height against time together with the correct graph but did not seem aware of this. There had certainly been no agreement following any discussion.

Episode 3 Aeroplane (1.37.32)

C: Height against distance, is it?

V: Yeh

C: Or height against time

J: Height against distance

C: Height against distance

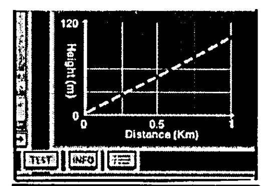
C: What choices are there?

Not that.

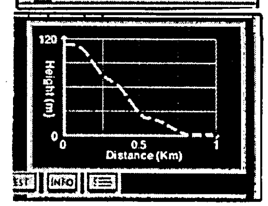
C: It might . . .

J: It might be that

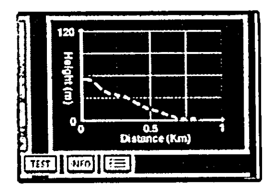
Referring to (1)



Referring to (2)



and (3)

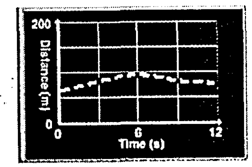


(in quick succession)

J:	Keep it still a minute!	Referring to (3)
	Is it that one	
C:	It comes down gradually, doesn't it?	
J:	Is it going down or is it on the flat?	
C:	It's the plane landing	
J:	I didn't	
C:	....	
C:	Try that	Still referring to (3)
J:	Test it. Yeh	Positive feedback from the system.
J:	Do the Cheetah	(No other options explored on this section).
:		
:		
:		

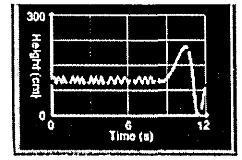
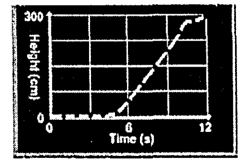
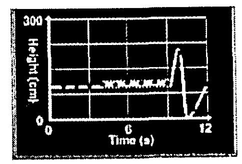
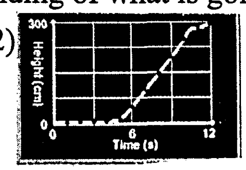
Episode 4 Cheetah (1.39.41)

J:	Shall we watch it first?	
V:	Yeh	
:		
:		Vicky and Caroline flick through the graph options.
J:	It depends what it's against though	Pointing to the choice of axes option.

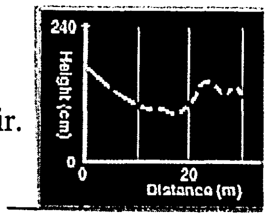
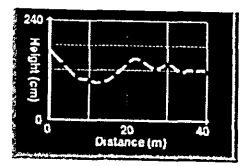
J:	Is it . . .	Referring to choice of axes.
	Try the other one	
C:	It's speed against time	
J:	Is it speed. I think its speed	Looking at the graph - thinking back from the graph rather than visualising how the speed changes and hence what the graph of speed against time might look at. 
C:	Try that	
V:	This one	Referring to (1)
C:	Yeh	
	Just try that and test it	No discussion as to reasons why.
J:	Hey. Is that right?	
	That's speed against time.	Again moved off this sequence without considering any of the other graph options.

Episode 5. Long jump (1.41.05)

V:	What do you want?	
J:	Long jump	
C:	Shall we watch it first?	
:		
:		
J:	Speed. Speed against time	They are looking at the graph and thinking about which axes fit the graph (rather than vice versa)
	Distance against time?	
C:	Distance against time?	

J:	Well its distance isn't it. It isn't height	Referring to (1) 
	Well it might be height!	
C:	It's distance against what?	
	. . . .	Referring to (2) 
	No it's not that	
J:	Is it that?	Referring to (3) 
J:	No! Yeh! No! No! Just tried one	
C:	Shall we draw it?	
J:	Oh no we'll draw it afterwards	
	Test it. Incorrect	
V:	Its wrong	
J:	So that means that that's wrong. It might not. It is.	Pointing to the choice of axes (as opposed to the choice of graph). (Vicki playing little part other than controlling the mouse - seems to have little understanding of what is going on.)
	I suppose if it's distance she's getting faster isn't she?	Pointing to graph (2) 
		Positive feedback from the system - but they did not seem to understand why this was the correct option.
J:	What are we doing now? Birds or high jump	Again they leave the section without exploring all the graph options.
C:	Shall we do 'birds'?	
V:	Birds	

Episode 6 Birds (1.42.52)

J:	Never mind Vicki!	As the long jump sequence begins to play!
	(Laughs)	
J:	Are you telling me you're good at computers, Vicki?	
	(Laughs)	
V:	I pressed the er . . .	
J:	Good on Nintendo! (Laughs)	
V:	Yeh!	Vicki reselects.
J:	It goes like up, up and down	Making a wavy flying motion in the air. 
	I don't think it's that one	Referring to (1)
C:	It's going down though, isn't it?	
	It's either that one or the one before it	Referring to (1) or (2) 
C:	What's that? Distance?	Referring to choice of k axis.
	Try that	No reasons given or discussion.
J:	Try that one	
V:	Gosh that was good!	
J:	Well we got one right	Again they move on without fully exploring the sequence.
	.... high jump	

Episode 7 High Jump (1.44.59)

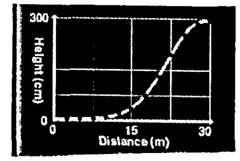
They view the video sequence and then flick through the graph options.

Referring to (1) — Again the choice of axes has not been clarified.

J:	We haven't done the 100 metres either, have we?	
C:	No	
V:	It might be height	
J:	It might be that one	(Note: a contribution from Vicki here)

J: I think it might be that one, but it doesn't show her coming down bit

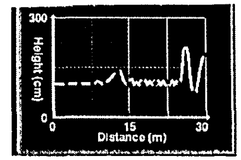
Pointing to graph (1)



J: Why would it go up there?

C: Because she jumped up. She did a skip

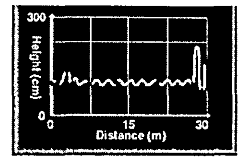
Pointing to first blip in graph (2)



C: I think it might be that one

V: Shall I try that one?

Referring to graph (3)



J: It must be, cos it would have said incorrect

C: Shall we just do the 100 metres?

J: Yeh

C: Just do the 100 metres

Vicki makes selection of (3)
The system plays the sequence with graph overlay.
Again they leave the sequence prematurely. No real discussion or reasons given. Little understanding demonstrated. More guesswork than anything. Hardly any contribution from Vicki.

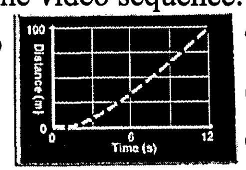
Episode 8 The 100 metres (1.46.28)

C: .... distance against time?

J: It is distance against time

C: Let's look at the choices
mmm
Test

Each time they have taken the choice of axes as those set at the start of the sequence, as they do again.
They view the video sequence.
Referring to



They seem quite sure about this one. (Covered in whole class situation earlier)
Positive feedback given from the system. They finish with little discussion.

APPENDIX 3

ASSOCIATED PUBLICATIONS

LISTING

HUDSON, B. and GILLESPIE J., (1991), Trees/Neighbourhood, Stanley Thornes, 1-24

CENTURY MATHS, (1991), Domesday Help Guide: Year 7-8 Worksheet Pack, Stanley Thornes, 10-17

BUXTON, P; HUDSON, B; GILLESPIE J; MILN, J; EYLES, J and SINGH P., (1991), Theme Teacher's Support Pack 1, Stanley Thornes, 67-82

HUDSON B., (1990), Interactive video in the mathematics classroom, Mathematics in School, 19, 1

HUDSON, B., (1994), Groupwork with multimedia in mathematics, British Educational Research Association Conference, 1994

HUDSON, B., (1994), Groupwork with multimedia in mathematics: contrasting patterns of interaction, British Society for Research into Learning Mathematics Conference Proceedings, December 1994, 46-56