An examination of how children read the time

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by

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Declaration

The work herein was carried out at Durham University between October 1988 and October 1989. It has not been submitted for a degree at this or any other University and is the author's own work unless otherwise indicated by reference.

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Abstract

Telling the time seems to be a problematic area for both children and teachers. This project considers how young children come to master our system of measuring and using time. Empirical work focusses on the development and use of a test procedure to evaluate time telling and setting skills in young children. Subjects comprise one hundred and twenty primary school pupils between the ages of six and nine years. Children are required to read time from analogue and digital representations on a computer screen and set time on 'real clocks'. Established educational practices are reviewed from structured discussions with class teachers and school mathematics co-ordinators, and through observation of classroom practice and resources.

An extensive analysis is made of children's performance and the nature of their errors. Children are found to perform poorly on reading tasks, and their scores are much lower for reading analogue time than digital time. The number of correct answers obtained on setting tasks are even less. These findings suggest that young children's understanding of our devices for measuring time are not as developed as they would be appear from a consideration of reading ability alone. Children are found to exhibit an enormous range of misunderstandings, and an examination of the nature of these, highlights the features of visually-coded time that are conceptually difficult for young children to master.

The quality of young children's time telling environment at the level of the school and the class, is found to be largely deficient. This situation is presented as a contributory factor to the low performance of subjects on the test. Finally the numerous suggestions for effective teaching methods in the literature are summarized to give some idea of the range of approaches possible, but researchers are criticised for failing to properly evaluate their proposed instructional methods.

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CHAPTER 1: INTRODUCTION

1.1 THE PROBLEM

1.1.1 The Difficulty Of Developing An Understanding Of Time

In the Western world our lives revolve very much around the clock. Throughout each day deadlines are continually having to be met. Without the ability to tell the time, we cannot keep appointments to arrive on time for work, to meet friends, or to watch a favourite television programme. Without a sense of time we are unable to order our own experiences and make sense of our environment. Thus to participate fully in life, a good understanding of time and the ability to tell time and use it properly is vital. Most researchers in this area acknowledge the importance of acquiring time skills (eg. Barcott, 1973 and Bachrach, 1973). Benoit & Valeno (1962) believe its importance extends further in that it is a vehicle for other learning.

Time seems to be one of the most problematic areas of the primary school curriculum for both teachers and children. This is not surprising when we consider that time is abstract, we cannot see an 'hour', but must experience it. When we ask children to learn our systems of representing time, we can only show them what one o'clock looks like on a timepiece, not what it 'is'. Burton & Edge (1985) highlight that even clocks and sandtimers only measure the passage of time indirectly. They point out the difficulty of finding concrete examples for the direct measurement of time.

The complexity of the situation is increased because the experience of time is subjective, an hour spent pleasurably appears to be a shorter period of time than it actually is, whereas an hour spent on a boring task appears to be a much longer interval of time.

Furthermore, the way in which adults use the language of time is confusing for young children. As Burton & Edge (1985) point out, words and phrases dealing with time are often used in an informal manner as well as a precise one, in the daily environment of children, for example adults often say "in a minute" when they really mean a longer period of time. This occurs at a stage when children understand even the simpler words of temporal vocabulary, such as "before" and "after" in a different way from adults.

1.1.2 The Nature Of An Understanding Of Time

The development of the ability to identify time on a clock and the acquisition of some concept of what time is are particularly difficult skills both to learn and to teach. The skills involved in mastering such concepts are numerous.

There is an important distinction here which must be made between the concept of time and telling time, as the skills involved in each are very different. The concept of time can be thought of as the acquisition of some concept of what time is. Telling the time, on the other hand, can involve simply the identification of time on a clock. At its barest, it is a process of "cracking the code" of the system we happen to have developed for measuring time in our culture. This is the way in which it is viewed in this study. However it can also include the 24 hour clock, the use of timetables, and the calculation and manipulation of time intervals.

Before identification of time can be learned, there are certain basic understandings that must be grasped, these include recognition of the ability, and to some extent, the necessity of measuring time; recognition of a clock as a device to measure time; and understanding of time as a uniform progression.

The skills involved in the identification of time include the ability to recognise and differentiate the two hands; recognise and identify the numbers 1-12; count from 1-60, by ones and by fives; match minute metric numbers on to clock face numbers; and read the correct metric for each hand.

The difficulties have been added to by the recent introduction of the digital representation of time and the twenty four hour clock, so that there are now many ways of presenting and recording time.

1.1.3 The Development Of An Understanding Of Time

These particular demands associated with the cultural device of clocks, offer a particular representational system that has to be mastered and so call upon information processing skills. Thus interest in clock reading must necessarily look towards the psychological domain.

A good concept of time seems to develop over a long period, after much repetition and reinforcement of learning. Our basic fluency with time concepts is established during the early primary school years, although further development continues well into the senior school (eg. Gothberg, 1949).

The ability to tell the time also seems to be acquired over several years, often beginning as children enter school and spanning the junior school years. Although it is acknowledged that we impose upon children a particularly ugly representational device for handling the code of time measurement, this long period of development would seem reasonable only if learning about time *does need* to occur over so many years. Otherwise, if children are taking longer than they should to acquire time telling skills, we must infer that there is some lack of efficiency in the way in which we approach the teaching of time. This view is supported when we consider what occurs during the primary years. Children form models of a clock that are increasingly exact approximations to the reality, but the process itself appears to be strewn with a surprisingly large number of misunderstandings.

In the literature many of the time telling programmes proposed are based on systems already operating in the author's own class. They are designed for use over short periods, such as a term or a year and yet they still report considerable success, although this is usually not evaluated in any formal way (eg. Thompson & Van de Walle, 1981). However, Nibbelink & Witzenberg (1981) do detail a study involving short term intensive tutition comparing their own method with the traditional one. The pre-test to post-test gains for both methods are considerable.

Thus the inference from the work to date is that the teaching of children to tell the time can be done over a relatively short space of time, since it can, to some extent, be broken down into a small number of rules which probably can be learned quite quickly with appropriate teaching. Yet, as described above, teaching children to tell the time is considered by educators to be an extremely difficult and lengthy process. Thus, in the light of the available research, we are left asking why it so often takes children so long to learn to tell the time. For the majority of children, the issue would appear to be captured by Nibbelink & Witzenberg 1981 "The problem, then is not that people fail to acquire the skill, but rather that it is not acquired efficiently".

What is required then, is an understanding of how children come to master the skills in "cracking the code" of time measurement. These problems can be tackled by an information processing approach. By discovering how it is that children come to be familiar with time telling, a functional teaching approach can be developed, which is geared towards matching the progression of these skills.

Even those studies which do report progress using a certain instructional programme (eg. Nibbelink & Witzenberg), are not grounded in this understanding. Unfortunately the literature to date does not approach the subject in this manner, it merely acknowledges the problems of teaching time telling and presents suggested teaching methods. Hence there is a clear need for a normative study to consider just how useful an information processing approach would be and to evaluate the severity of the current situation.

1.1.4 The Time Telling Environment

To probe further why it is that children's needs in time telling do not appear to be being met, we can turn towards the more practical problems of teaching time. There seems to be a glaring lack of systematic classroom practice. Even a brief look at the time telling literature will reveal the enormous number of approaches used to teach time, both in terms of the methods and the sequences in which time telling skills are taught. Sequences used, include the traditional sequence of o'clock, half past, quarter past, quarter to, five minute points, and one minute points; the "to/past" method in which all times from the hour to the half are referred to in terms of minutes past the hour and all the times from the half hour to the following hour are refered to in terms of minutes to the hour; and the "minutes past" method in which times are read as minutes past all the way round the clock.

Now with the introduction of digital time, there is an added choice as to whether to teach analogue and digital time together, separately, or only to teach one of the two representations. The situation has developed in this way because there is little consensus of opinion, and no prescription, as to the most effective method of teaching time.

As an extension of this trend, there seems to be little integration of teaching between classes and therefore continuity of teaching and learning from one class to the next is likely to be limited. Teachers in one class do not always seem aware of what teachers in another class have done and will do. If this is indeed the case, teachers will only be able to guess at the attainment levels of their pupils and so will be unsure of where to begin teaching. This may lead to the dangers of unnecessarily repeating teaching, or worse, over-estimating standards and beginning teaching at a level above that of the pupils.

As with teaching all subjects, a very wide range of ability must be catered for, although in most cases the extent of this variability is unknown as there are no optimal assessment methods and no time to measure ability in an already pressurised curriculum. Added to this are the previous and ongoing home influences which are also unknown. Children come to school with hugely differing levels of knowledge and ability in both the concept of time and telling time and it is difficult for teachers to know where children are starting from, especially since there is usually no deliberate policy to measure individuals' levels.

Available resources also vary widely, so that there are many possible learning environments to which children can be exposed. It seems from informal observation of classrooms, that resources for time teaching are often poor. This is partly a financial problem; what money there is, tends to be channelled towards 'priorities' such as computers, books, maths schemes, etc, rather than specific resources for a relatively small topic such as time. Also, teachers are not always aware of the range of resources available to aid teaching about time, or of their relative merits. Some resources are not used to their full potential, for example the computer could be used far more widely as a supplementary resource for the teaching of time.

1.1.5 Conclusion

From a consideration of these factors, it can be seen that the study of teaching children to tell the time is a worthwhile aim which should not be overlooked. Time seems to be a problematic area in which both teachers and children experience considerable difficulties. It is a particularly difficult topic which has been complicated recently by the introduction of digital time. Time itself is abstract, the experience of time is subjective, and the language of time is corrupted by adult use. The enormous range of ability possessed by children, together with the varying home influences, both of which are difficult to measure, contribute to the difficulties inherent in this topic. Added to this is the apparent lack of a systematic teaching approach which can be followed through as a child progresses through primary school, with an emphasis on integration. In the area of resources there also appears to be room for improvement.

In spite of the enormous number of difficulties encountered in learning to tell time, educators must not lose heart. We are fortunate that children seem to be highly motivated by mechanical instruments, and have a strong desire to understand their environment and emulate adults. For these reasons, Peterson (1973) states "it is one of the most enjoyable and rewarding topics to teach".

What is needed is a thorough review of present classroom practice in time telling instruction, within the wider setting of school policies on mathematics, to confirm just exactly what the present educational climate is, and whether the extent of the problem of teaching children to tell time is indeed, as severe as it appears to the casual observer.

1.2 THE APPROACH

1.2.1 The Concept Of Time And Telling Time

Those researching time have generally divided the acquisition of time understanding into the two main areas of the concept of time and telling time. Horak and Horak (1983) describe the concept of time as involving the ability to sequence events and understand duration, and telling time as comprising reading a clock, recording time, and predicting times after certain intervals. They believe these two areas should be taught in parallel, as do the majority of workers. Schultz (1979) describes the two components of achieving a working knowledge of the concept of time as learning to tell time and using time intervals, and says that the two must be coordinated, although teaching tends to concentrate on the latter. In the classroom, the main distinction can be thought of as that between the structure of the day which the teacher is carefully creating verbally and by the provision of experiences, and the metric which allows one to code that structure.

Greater concern about childrens' levels of attainment has been directed towards their grasp of the concept of time rather than their ability to read time from a clock. This is due to the complex nature of the understandings, the development of which spans a considerably larger number of years than that of telling time and is hence more difficult to measure (eg. Burton & Edge, 1985).

Some researchers are so concerned with the sheer enormity of the problem of understanding the development of the concept of time, that they dismiss learning to tell the time as a simple dial reading activity. It *is* true that a clock, particularly a digital one, *can* be read without a grasp of the concept of time, but ideally the two should be taught in conjuction so that they develop together.

There is a case for studying, and even teaching the two separately. For example, Thompson & Van De Walle (1981) point out that telling time and acquiring time concepts are not necessarily related. However, it is a widely held belief amongst researchers, that the most effective instruction is that which combines the two, allowing them to develop together over a long period (Thompson & Van De Walle, 1981; Horak & Horak, 1983).

1.2.2 The Relationship Between The Concept Of Time And Telling Time

Clearly there will be an important relationship between learning to read time on a clock and mastering the concept of time, but this has received very little attention. The extent to which each is affected by the other, and at what stages of development of one is the other of greatest importance are yet to be examined.

One reason why the study of the two together and their interaction would be valuable is because access to clock reading skills and the general representational device of the language of clocks, could well be a stimlus for more mature thinking about time. This relationship does not however, preclude the two from being studied separately, as in many studies, including the present one.

The challenge then is not only to develop a firmer base for good educational practice: there is a more purely theoretical motive for exploring children's development of time concepts. Contemporary understanding of how children develop their earliest conceptual knowledge suggests a significance for the typically structured and predictable character of their daily experience (Nelson, 1986). It has been proposed that this "scripted event knowledge" forms the child's foundation for recognizing and forming many new concepts. The details of this claim can not be elaborated here, but there is a clear implication that the structure existing within children's typically "scripted" experience is of some developmental importance. If so, we are bound to consider how fluency with the metric of time might reinforce the child's capacity to reflect upon such structure. Such questions remain in the distance of this project but any practical progress in faciliting children's mastery of time concepts should lead towards a practical consideration of these issues.

Psychological interest, in addition to such theoretical dimensions, also has relevant practical considerations. There are practical problems of how best to communicate to children the concepts of time - which are highly abstract - and also problems of how to teach its somewhat inaccessible representation on clockfaces. The latter challenge appears most tractable and, thus, serves to define a good starting point for psychological research. It requires that we establish the cognitive demands children experience as they are taught to internalize our visual representation of time.

1.2.3 The Neglect Of Time Telling

Considering the importance of time, it is surprising that there is not a greater wealth of relevant literature. The existing literature on teaching children to read a clock comes from two main sources. As well as being researched by academics, the topic is often in case study form, presented as an individually developed programme or set of observations, based on professional experience in the classroom. Work from both these sources, but more often the latter, tends to give little or no reference to the work of others in the same field (eg. Thompson & Van de Walle, 1981; and Krustchinsky & Larner, 1988). The work lacks a common thread and there is little consensus as to the relative merits of the various approaches to teaching time. It is therefore difficult to clarify the present state of the work and to observe a particular route of progress; rather one is left with the impression of a circular motion without a fixed goal in sight.

In spite of teaching children to tell the time being a problematic area for both children and teachers, it seems to be an area of education that has received relatively little attention. Nibbelink & Witzenberg (1981) concluded, from reviewing mathematics textbooks, that there is not a fixed place in the curriculum for time. They found it is often ignored or at best given a few pages at the back of the book. Bachrach (1973) also found very little material on time telling in textbooks. In fact, she found no basic mathematics book that devoted more than four pages to telling the time, and commented "Sometimes telling time is left for incidental learning, and often it is completely overlooked or is only haphazardly presented". A perusal of the national mathematics schemes in current use in this country results in the same conclusion. Sadly, even the National Curriculum has failed to change this situation.

This neglect is partly because many people consider time telling to be a skill which children just acquire through incidental exposure. Eventually, one way or another, most children do develop the ability to identify time before adulthood. Benoit & Valeno (1962) suggest that normal children pick up time telling through only casual hints from adults because they are well motivated.

1.2.4 Reasons For The Neglect Of Time Telling

Some children with special educational needs do not develop the ability to identify time. For this reason, the majority of interest on this topic has focussed on such children, and overlooked the problems encountered by children in general. Schultz, for example, believes that "somehow or other, but largely on their own, all children eventually learn to tell time." This underestimates what children need to be taught and the benefits of studying how they are taught it. There is no doubt that instructional methods vary widely and lack the efficiency of a clearly defined optimal strategy with a substantial basis of proven results.

A considerable amount of the research interest on children learning to tell the time has centred on children with special needs (eg. Benoit & Valeno, 1962; Hofmeister & LeFevre, 1977; Krustchinsky & Larner, 1988). The attention of educators has been drawn to these children as their difficulties are more salient than those of other children. They can experience considerable problems in learning to tell the time and there can be a real possibility that some of them may fail to attain the required skills to enable them to use and tell time accurately if teaching is not geared specifically to their needs. Peterson (1973) believes that learning to tell time is one of the most difficult measurement skills for mentally retarded children, they may use a digital clock as adults, but never really seem to understand time concepts. He stresses that a student who does not understand the concept of time as a continuous process cannot achieve the experience of time.

These authors emphasise that children with learning difficulties require different or adapted teaching methods to overcome specific difficulties they may have. Krustchinsky & Larner (1988), for example, worked with learning disabled students, many of whom had visual-perceptual difficulties, so they introduced the two hands separately. Britton (1981) agreed that many children with learning disablities find it difficult to tell time from a two-armed clock. Hofmeister & LeFevre criticise many of the existing teacher materials for failing to provide a method of teaching time telling that is sucessful with retarded or learning disabled children. The vital importance of being able to tell time for everyday life makes this a very pressing problem.

1.2.5 The Present Approach

This project was inspired by some pilot observations which involved asking children to read some analogue times on a real clock as a way of evaluating the effectiveness of a computer programme designed to teach time. It became clear that there were a large number of misunderstandings and that even answers that appeared at first to be completely wild guesses, were usually based on some strategy, however obscure.

The starting point is to consider the problem of reading the time: mastering the representation of its metric. In an important sense this is a problem of "cracking a code" - internalizing the rules governing a visual format we happen to have evolved for symbolizing time. We must aim to understand the cognitive demands on children as they try to extract a given number of minutes and hours from a given visual representation. Of course, in practice, no teaching will actually treat clocks in quite this way: simply as carriers of arbitrary codes to be cracked (as if the answers did not relate to anything in the child's experience). However, the decoding exercise remains at the root of what must be achieved and, for research purposes, it can be harmlessly decoupled from any associated efforts to give meanings to particular times or durations.

In time telling, we are asking children to decode symbolic material: they must have an understanding of numbers, map this on to a system of coding that has been arbitarily developed, and follow the rules of this system. We need to appreciate their spontaneous mis-interpretations in the light of the demands we are making on them.

1.3 THE PROPOSAL

The proposal is to gain further understanding of the way children approach the task of decoding our complicated representational systems of time, using both cognitive and developmental facets of psychology.

The approach must be to discover how this decoding is taught and how it is learned. Since the literature does not consider questions of this type, it is not reviewed prior to the study. Instead, the following steps are proposed to approach these questions. The first step will be to develop a test which efficiently measures time telling and setting skills. An assessment of children's performance on the test, and an examination of the nature of their responses, should contribute to an understanding of the way children master this skill, and the developmental patterns that exist. Moreover, the construction of a taxonomy of children's misconceptions should be possible, which will give an indication of how widespread difficulty in learning to tell time actually is. These insights will have implications for educational practice which, it is hoped, will go some way towards meeting the real needs of teachers in the classroom.

An additional aim will be to convey something of the state of existing classroom practices. There seems to be a lack of systematic practice in this area of the curriculum and it would be a useful background to highlight how far this impression is justified. To gain some measure of the spread of different methods of teaching time and of the effectiveness of these and also to shed light on the problems encountered by both children and teachers, semi-structured conversations, using as a base a list of questions, will occur with the teachers of the pupils who will be subsequently the subject of study. This will not be a representative survey, that is, reflecting the relative frequency of different approaches. Rather, it will aim to convey the variety of strategies that occur in typical classrooms, and so provide normative data on the scale of the problem.

Thus in the next chapter, the development and administration of both a thorough testing procedure to tap children's knowledge of the way we measure time, and of a survey method to sample the school and classroom environment, is described. The results obtained on the test are presented in chapter 3. From an assesssment of children's performance and a systematic analysis of their errors, the aim will be to highlight the features of reading and setting both representations of time that are conceptually difficult for young children to master.

In chapter 4 there is a further discussion of the performance of subjects, as well as an attempt to account for the patterns of response observed, in the light of the normative survey data collected. Lastly a review of the wealth of suggested techniques for improving the teaching of time, suggested by the literature, will be reviewed in chapter 5.

CHAPTER 2: PLAN AND IMPLEMENTATION OF THE INVESTIGATION

2.1 THE SELECTION OF SCHOOLS, CLASSES AND SUBJECTS

2.1.1 Schools

A meeting with the Durham County Primary Adviser resulted in the allocation of seven schools to the project, in and around Durham City. In fact only four schools were used, as the number of subjects was found to be sufficient for the proposed study and the pressure of time precluded the use of further schools. The four schools were chosen to reflect a variety of catchment area. To convey something of the flavour of the schools, a description of them is given below. Two additional schools (A and B) were used as sites for pilot and reliability studies.

School A is a village school situated just outside the city of Durham. The majority of pupils come from a working class community with limited social and economic resources. The layout of the school is semi-open plan. There are about 130 pupils accommodated in 5 classes. There is one reception class, one middle infant class, one transition class, one second/third year junior class, and one third/fourth year junior class.

School B lies on a housing estate a few miles out of Durham city. It serves a middle class community and has high academic standards. The infant school has a semi open plan layout, with parallel classes in the two top years, and one reception class, so there are five classes in total. There is also a nursery. There are about 140 children in separate junior and infant buildings with separate head teachers.

School 1 is situated in a village a few miles out of Durham city, and is attended by pupils from both middle and working class backgrounds. It is a relatively new school formed by the merging of an infant and a junior school, but occupies an old building which has separate classrooms. There are about 170 pupils accommodated in seven classes, with one class for each year from first year infants to fourth year juniors.

School 2 is a town school serving a predominantly working class community. It is very well resourced due to an initiative by the recently appointed Headmaster and influx of money. There are approximately 180 pupils in seven classes, in the primary school, and an additional 40 children in the nursery.

School 3 is a city school with pupils mainly from middle class homes. A high proportion of families have academic connections with the university, so achievement levels tend to be high with considerable parental support, though some pupils may have been considerably mobile. There are separate infant and junior schools, with separate heads, which are situated on land next to each other. Although the two schools do not work closely together, there is some communication and sharing of resources. The infant school has about 130 children in six classes. There are two parallel classes in each of the three infant years. The Junior school has about 190 pupils in eight classes. There are two parallel classes in each of the four junior years.

School 4 is situated on a housing estate in the city of Durham. The children are from a working class community with considerable social and economic deprivation. There are separate buildings for the nursery, the infant school and the junior school within the same area. There used to be separate infant and junior school, with their own heads, but they have recently been merged. About 180 pupils are accommodated in seven classes, there being one for each year group. In addition, there is a nursery with about 80 pupils, in two sessions.

2.1.2 Classes

The study was limited to three classes in each school, to keep the number of subjects to a manageable level. The optimum ages to observe the greatest development of time telling skills were unknown, however work previous to this study had shown the last year of the infants to be a productive stage of learning to tell time. So the initial plan was to begin with third year infant pupils and depending on the level found there, either to go up to junior one (J1) then junior two (J2), or up to J1 and down to infant two (I2). Thus the classes actually used could be different in each school.

In fact, from talking to teachers, it became clear that second year infant pupils have often only been taught o'clock and half past, so the test would be unsuitable for them since it covers the whole range of possible levels of telling time. For this reason subjects were actually taken from the last year of the infants and the first two years of the juniors in each school.

2.1.3 Subjects

2.1.3.1 Pupils

Ten children were chosen randomly from each class to be interviewed. This number of subjects would be sufficient for statistical analysis but small enough to allow the testing of subjects in a variety of clases and schools, to maintain a broad perspective.

Where there were parallel classes, one class was picked at random and from these pupils, the required ten subjects were selected randomly. In School 2, children of one year group were split according to age, so the ten subjects required were taken randomly from the two classes combined.

The overall distribution of sex of the pupils was 52.5% male and 47.5% female.

2.1.3.2 Teachers

In order to study the development of time telling in its educational context, it was planned to compile an overview of the range of approaches to this curriculum topic. At first, the possiblity of a broad based survey around the county was considered but this idea had to be abandoned because of financial and practical constraints. The survey therefore had to be limited to a smaller population and that of the class teachers and the schools mathematics co-ordinators of the subjects was chosen. This had the additional advantage of allowing for the relation of particular factors of teaching strategy to test performance and errors - in order to comment on their relative effectiveness, and illuminate the cognitive processes occuring.

2.2 DEVELOPMENT OF EMPIRICAL RESOURCES AND PROCEDURES

2.2.1 Survey Of Teaching Practice

To determine the place of time-telling instruction in the curriculum of the class and school, obtain some idea of what teachers actually teach and to what extent, review the available resources and the extent of their use, and collect information on the common problems encountered in teaching and learning time, it was proposed to interview the class teachers of the subjects and the mathematics co-ordinators of each school. By mathematics co-ordinators is meant the person in the school who is closest to the "general mathematics policy". There is often a member of staff especially appointed to a position to oversee the running of mathematics within the school. This can be a teacher or the headteacher.

Through such an investigation the general test data would be supplemented by information on the teaching environment, methods, and content, to which subjects had been exposed, as well as some insight into the general problems encountered in teaching time, and proposed solutions. The enquiry would give some idea of the range of practices occurring in schools, rather than providing a representative sample of the population.

The possible types of survey were evaluated. A straightforward self-completion questionnaire was rejected on the grounds of being too formal and constricting. The provision of response categories was rejected in favour of an emphasis on teacher-generated answers, partly because of uncertainty about the nature of the responses and partly to minimise interview interference. It was hoped to generate as much relevant material as possible without leading interviewees along a particular route. So an informal discussion method, centred around a list of questions, many of an open-ended nature, was used. Responses could be kept to the point by the interviewer who would prevent the conversation from straying too far from the main areas of interest.

A list of questions was constructed and a concerted effort was made to ensure that these were clear and unambiguous, not irritating or offensive, and were not worded in such a way as to suggest to respondents that there was only one acceptable answer. This was then piloted to ensure it comprised a workable approach to illuminating the young child's time telling environment.

2.2.2 The Test Of Time Skills

For a full examination of children's understanding of time, a consideration of both analogue and digital time is necessary. Digital time can no longer be omitted from time telling instruction as it is now so widely in use.

Most interest in this study was directed towards reading time, but some work was also oriented towards setting time, although it is a more difficult problem to tackle, and the yields may add only slightly to those obtainable from looking at reading time.

Thus four aspects of time understanding and knowledge need to be measured...

1) the ability to read analogue time
2) the ability to read digital time
3) the ability to set analogue time
4) the ability to set digital time

In considering how best to evaluate these factors, it was necessary to address the issues of question design, presentation medium, and response method.

2.2.2.1 Question Design

Since it was impossible to make any firm judgements about which of the four factors of time understanding would be most useful in illuminating the cognitive processes occurring in the development of time telling skills, they were given equal weight in the test.

However, there were some suspicions that the reading of digital time might be too simple a task, even for the youngest children in the study. For this reason, the placing of this task at the beginning of the test, in order to put children at their ease, was considered. But, in fact, in order to avoid problems of bias, an alternating order of presentation was decided upon.

By maintaining the broad perspective provided by these four test domains, the number of individual questions had to be minimized to keep the test to a reasonable length. This arrangement seemed likely to yield the most interesting material. Bearing in mind these economies, it was still necessary to cover all types of time telling questions in the test. The relative importance of different types of times had to be weighed up in order to work out how many questions there should be on each.

It seemed from initial observations of the types of errors that children make when learning to tell the time, that quarter past and quarter to are both sources of a large number of mistakes, but whether more errors do actually occur on these points of the clocks than on others, or whether one is simply more aware of them, is a debatable point amenable to empirical verification.

To highlight the quarters would fit in with the traditional approach to time telling instruction. Nevertheless, it is hard to justify separating the quarters, partly as it draws attention to them and thereby perhaps makes them easier, partly because the asymmetry seems to presuppose the quarters as being more salient, and partly because it demands a less neat statistical analysis later on.

The o'clocks, it can be argued, are different in two senses, firstly the children need something they can probably cope with to give them confidence at the outset, and secondly the qualitative distinction between "hours" and "hours and minutes" is more striking.

It is important here to bear in mind the purpose of the tests, that is, to give a general picture of the development of time telling and setting skills and of the types of errors that can occur. If a given type of error is not truely idiosyncratic but occurs in a sensible number of learners, it will be detected within the total sample. Thus it is not necessary to structure times for individual subjects since overall the times presented will cover the spectrum, and the distribution of errors between subjects is not an issue that can be covered within the scope of this study.

It was decided that the test should comprise the following three parts...

a) 4 questions on the o'clock,

b) 11 questions on each of the remaining five minute points,

c) 6 questions on any one minute point.

These seemed to fulfil the optimum balance of investment of time and yield of data, maximizing information gained whilst keeping the test to a realistic length.

There were 21 questions on each of the four test domains, giving 84 questions in total. The test therefore required a substantial amount of work on the part of the subjects, but it was hoped that the variety of tasks would avoid this being a problem.

Times were well distributed around the clockface. The generation of times was specified according to the following rules...

a) O'clocks: 4 questions chosen such that there was one example from each of: 12-2, 3-5, 6-8, 9-11.

b) Hours for the 5 minute questions chosen such that there were no repeats. Five-minute points then randomly allocated to those choices.

c) Hours for the single minutes randomly chosen and randomly allocated to the minutes. Minute points chosen such that each of the following intervals was represented once (of course, the 5-minute points within the intervals not allowed): 1-9,11-19,21-29,31-39,41-49,51-59.

2.2.2.2 Presentation Medium

Times to be read and set could be presented to children either by showing them a picture of a clock, a real clock, or a clock on a computer screen. In addition to these methods, times to be set could also be given using verbal instruction.

Pictures of clocks were rejected as being impractical since they would be difficult to produce and time consuming to present. For reading time it was decided to pilot the other two options to see whether time on a real clock and time on a computer screen were equally well received by subjects. It was acknowledged that the use of the computer to present times would be a useful practical aid, as far as the administration of the test was concerned. This is because the computer could be programmed to generate and record times given.

The use of verbal instructions to set time was decided against because it would be confusing as there are often several ways of expressing a particular time, and there is no way of knowing the variation to which a certain child has been exposed and will respond best.

Therefore the only remaining methods of approaching setting questions was showing the subject time on real or computer clocks. As they could not be asked to set the time shown, the best alternative seemed to be to ask them to set the *same* time in the other representation. This would have the added advantage of also giving information on children's ability to transfer from one representation to the other.

For purposes of economy, children were asked to read a time in analogue or in digital form and then setting was measured by asking them to set the *same* time in the other representation. In this case, there is the objective presentaton of the time on the clock as well as the child's own verbal statement of what he believes it is. This has the balancing disadvantage of the child tending to set the time he has read, and if this first response was incorrect, then he may well also respond incorrectly to the setting part of the task. Of course the problem is that by handing over the definition of the setting stimuli to the child, there is no longer a random selection of all the times that would have been possible as problem stimuli. There seems to be no way to avoid this intrinsically difficult problem of how to ask children to set time. However the emphasis in directing the children was for them to make both clocks say the *same* time, rather than to set the time they had read. It is hoped that this went some way towards diluting the above mentioned effect.

Thus the test consisted of two sections presented alternately...

> **Section I:** Reading analogue time and setting the same time in digital format.
>
> **Section II:** Reading digital time and setting the same time in analogue format.

2.2.2.3 Response Method

Possible response methods for reading time are verbal, written or multiple choice (either on computer or paper). For setting, written and multiple choice responses are also possible, verbal responses are not satisfactory, but clocks, either real or computer-based, can be adjusted so that subjects can show what they think the equivalent time is.

A written test is rather time consuming, and has added problems due to the degree of accuracy needed and the lack of ability to be precise about the position of hands on a small clock face, so was rejected. Multiple choice was given some consideration but eventually decided against on a number of counts, largely because of the difficulty of deciding upon the alternative answers to present. There would need to be a great number of them as all types of possible errors would need to be available, as well as a couple of totally unrelated times, so that it could be inferred that any subject who chose one of these did not have any idea of how to tell the presented time. There is also the danger of leaving some out.

A child-generated response would seem to be much more reliable than an adult-promoted response. So for reading, it was decided to allow children to respond verbally to times given.

By the same token, the setting of real or computer-based clocks was favoured as a response method for setting times. Again, because of the practical advantages of the computer, a pilot study was proposed to evaluate the two methods. It was necessary to ensure that the adjustment of an on-screen clock from the keyboard is a comprehensible task for children and therefore a sufficiently accurate reflection of ability. Thus a real clock version of the test and a computer-based version were designed so that they could be compared in a pilot study.

2.2.2.4 Design of Materials

A computer programme was written by Dr. Crook for a BBC'B' (available from the author). It selected a sequence of either analogue or digital times and presented them in random order. At the start of the programme a data file was named and a test section selected. Each new target time and clock to be set could then be displayed by a key press.

The computer analogue clock to be read consisted of a large circular and face numbered from 1-12, with one and five minute points marked, an hour hand and a minute hand. A photograph of the clock is provided on figure 2.2.

The computer digital clock to be read consisted of a simple set of numbers displayed in the centre of the screen, with a colon separating the hours and minutes.

The computer analogue clock to be set had the same appearance as the computer analogue clock to be read, but was ungeared so that the minute and hour hands could be moved separately, either forwards or backwards, using specially labelled keys. There were four keys marked by sticky labels, on the left side of the keyboard were two keys to move the hour hand, a green one to move it forward and a red one to move it backwards, and on the right side of the keyboard were 2 keys to move the minute hand, labelled in the same way.

The computer digital clock to be set consisted of a rectangular box with a colon in the centre, set at 00:00. The numbers were adjusted to set the clock. The two digits of the minute side of the digital clock moved together, either forwards or backwards, using keys labelled in the same way as for the adjustment of the analogue clock. keys. Similarly the two hour digits moved together. The numbers in the digital clock were not constrained in any way, any number from 1-9 could appear in each digit space, thus a child could set a time such as 70:80 if he wished to.

The real analogue clock to be read consisted of a typical analogue teaching clock with a clear face and an hour and a minute hand. It was geared for ease of setting by the experimenter.

The real analogue clock to be set consisted of a homemade analogue clock, with a clear face, numbered from 1-12, with one and five minute points marked. The two hands were ungeared to allow children to set impossible times. A photograph is provided on figure 2.4.

The real digital clock to be read and to be set comprised a homemade electronic digital clock. This consisted of a small box with four individual digit displays, each with a separate forward moving button directly beneath it, so that the numbers and buttons had one to one correspondence, and a colon in the centre of the clock. The possibility of two buttons only, one to move the minutes forwards and one to move the hours forwards, was rejected as it would take subjects too long to set times. Again digits were not constrained at all, so it was possible to set nonsense times, such as 97:18.

There were also test recording sheets with a list of target times to be set by the experimenter for the real clock test, and space to record subjects' answers, and blank test recording sheets to record answers to the computer based test.

2.3 PILOT STUDIES

2.3.1 Evaluation Of Discussion Material

A set of questions designed to gain information on the work covered and the methods used to teach time, was discussed on an individual basis, with teachers in School B. Similarly a prepared list of questions concerned with general school mathematics policy, with special reference to time, was discussed with the school mathematics coordinator.

In both cases an informal discussion situation was created. This allowed for a free exchange of ideas which was thought to produce better yields than a more formal approach, and since the conversations were not constrained in any way, it was possible to see what information the teachers came up with themselves. The focus was on determining which questions seemed to make sense and which did not, which questions were redundant and what additional questions should be asked.

The types and content of the questions were modified in the light of the responses and comments received.

2.3.2 Evaluation Of The Test And Test Materials

2.3.2.1 Method

An informal pilot study was carried out at School A to discover the most appropriate testing procedure and materials for gathering data about time telling skills. A computer-based and a real clock based version of the test were compared to see if there was any marked difference in the subjects' ability to function effectively with the two approaches.

The first year junior class in School A was judged from previous experience, to be a good starting point for time telling work. Ten subjects were chosen randomly from one of the two parallel first year junior classes. The first five subjects were given computer-based tests and the remainder were given real clock based tests. There were two sections to the test...

> Section I: identify analogue time, set equivalent digital time,
> Section II: identify digital time, set equivalent analogue time.

Subjects were alternately given section I or section II first, followed by the other section, directly afterwards.

The procedure was as follows...

i) Real Clock Test: times were presented and set on 'real' clocks.

section I: The geared analogue clock was set by the tester to the first target time listed on the test recording sheet. The child was asked to tell the time and then shown the specially designed 'real' digital clock and asked to set the digital clock to make both clocks say the *same* time. This was repeated for 21 target times.

section II: The 'real' digital clock was set by the tester to the first target time listed on the test recording sheet. The child was asked to tell the time and then shown the 'real' ungeared analogue clock and asked to set the analogue clock to make both clocks say the *same* time. This was repeated for 21 target times.

ii) **Computer-Based Clock Test:** times were presented and set on computer-based clocks.

Section I: The first target time was displayed on the analogue clock on the computer screen. The subject was asked to read the time. Then the experimenter pressed a key so that a digital clock set at 00:00 was displayed adjacent to the original analogue clock. The child was required to make both clocks say the *same* time, by adjusting the digital clock. This was repeated for 21 target times.

Section II: The first target time was displayed on the digital clock on the computer screen. The subject was asked to read the time. Then the experimenter pressed a key so that an analogue clock set at 12:00 was displayed adjacent to the original digital clock. The child was required make both clocks say the *same* time, by adjusting the hands of the analogue clock. This was repeated for 21 target times.

For both types of test, subjects' reading and setting responses were recorded by the experimenter on blank record sheets. The exact form of the vocabulary used to read time was noted. Analogue times set were recorded, hour hand, then minute hand, both in terms of minutes, to give a precise account of the time. Therefore 20 0 would denote 4 o'clock exactly, whereas 22 0 would denote an incorrect placement of the hour hand for 4 o'clock.

2.3.2.2 Results

One of the most striking results was that the test took far too long to administer, an average of between thirty and forty minutes per subject. After a while children became bored, interest waned and performance declined. They were simply being asked to do too much at one sitting.

As far as the materials were concerned, subjects seemed to have no problem reading the real geared analogue clock. Neither did the setting of the 'real' ungeared analogue clock appear to cause difficulties, though it was noticed that no child set the hour hand at any other point than directly on the hour.

The children coped satisfactorily with reading the 'real' digital clock. However one child thought that the two sides of the clock were different times and this may have been because there was rather a large gap between them. From the tester's point of view, it was problematic to set as it was easy to overshoot the required time.

Similarly, setting the real digital clock was not straight forward, as children often overshot the desired number. In fact in extreme cases, when a child repeatedly did this, the tester had to set the time according to the child's specifications. The one to one correspondence of the numbers and the buttons, rather than being a disadvantage, seemed to be easier than moving the hours and the minutes together, (as required on the computer test). Subjects were watched particularly for misunderstandings such as moving only the numbers on one side of the colon, or only the first number of each pair of numbers on each side of the colon, but this did not occur. The children seemed quite capable of independently moving two numbers to create a desired two digit number, such as 11.

Reading the computerised analogue clock did not seem to create difficulties for the children. However, setting the computerised analogue clock was problematic. Children found it difficult and were often confused. Clearly the task of moving the hands was not straight forward. There is obviously a considerable amount of cognitive activity that has to occur which is unrelated to the task of setting an analogue clock and therefore clouds the issue.

Children read the computerised digital clock satisfactorily. However it clearly needed to be larger, and a confusion, apparent only in one subject, but which may have bothered others, was that the 0, because of the line in the middle of it, was taken for an 8.

In setting the computerised digital clock, several subjects were confused that the minutes jumped from 0 to 59 when the backwards button was pressed, they appeared to have no idea what was going on. It appeared to be more difficult to relate the movement of the buttons to that of the numbers, than with the four individual buttons on the real digital clock. For reasons of one to one correspondence, an ungeared digital clock is clearly preferable to a geared one.

If a computerised analogue or digital clock were to be used for setting time, then a minute or two for demonstration and practice, would be required, as it is only by hands-on experience that the function of the keys is really understood and the children become confident that they can carry out the required manipulation.

Setting the computerised analogue clock seemed to be easier than setting the digital one, probably because it is easier to see the effects of pressing the buttons as the hands move and easier to relate this movement to the actions precipitating it.

2.3.2.3 Conclusions

The test was too long in its present state. To avoid having to reduce the number of questions, the test was spilt into two halves, so that section I and section II were administered on separate days.

The children seemed to have no more difficulty in reading the clockface on the computer than reading a real clock, it was clearly quite in keeping with their model of a clock. Therefore it was concluded that the computer should be be used to present the target time as this had the advantage of being much quicker than using a real clock, since the tester does not have to set each target time, and the computer can store times after generating them.

On the other hand, setting time in either form, on the computer does not seem to be a straight forward exercise. Although some children quite quickly got the hang of manipulating the computer clocks, and their performance after setting a few times on the computer may well have been comparable to their performance setting time on real clocks, this could not be said to be true for all subjects. However, all children do seem to cope well with setting time on real clocks. For these reasons it was decided that time should be set on real clocks.

2.3.2.4 Recommendations

Thus there should be computer presentation of both analogue and digital target times, and 'real' clocks should be used for setting both analogue and digital time, as children seem to enjoy being actively involved, and this variety of types of task should help maintain interest. An ungeared analogue clock should be used for setting analogue time and an unconstrained digital clock should be used for setting digital time, to allow for impossible times to be set.

Some slight modifications were also recommended in the light of the pilot work described. It was thought that the computer digital clock would be more comprehensible if it presented four numbers, rather than omitting noughts, so times would be presented in the format 04:05. This is in keeping with some ordinary digital clocks. Also the real digital clock must be revised as it was not satisfactory.

It would be interesting, and may shed some light on the most common error of reversing the hands, to ask each subject the function of the hour and minute hands, and it may also be useful to ask what each side of the digital clock tells us, as from their setting of both analogue and digital clocks, children do not seem to be sure of these basic facts. In addition they should be asked whather they have a watch and whether they have a clock in their bedroom, to get some idea of the kind of time telling environment they are exposed to at home. Asking these questions at the beginning of the test would have the value of getting subjects oriented anyway. Responses should be recorded in written form by the experimenter rather than risk the presence of a tape recorder.

In fact this approach was tried out in the above study and it was found that subjects tend to interpret the question "Do you have a watch?" as "Do you have a watch on today?"! Therefore the experimenter should be careful to emphasise that she is asking whether the child has a watch on his wrist or at home.

Both digital and analogue clocks should be reset to 00:00 and 12:00 respectively after every time set. One child was found to be setting time by counting from the point at which the hand was set previously, also some children sometimes leave a hand in the same position as it was set previously, and there may be a tendency to move the hand which is nearest to a required point.

The programme should incorporate a key which takes the programme backwards a step, so that if a question is accidently overshot, it can be retrieved. It should accommodate the entering of subject's initials at start of each test to avoid any mix up of which set of questions belongs to which subject.

Notes should be taken of subjects' methods, if evident, to aid in the understanding of the cognitive processes and error patterns occurring, since these are not always obvious simply from subjects' answers. In addition, the range of vocabulary that is employed to tell the time should be recorded in the answer format for later analysis.

2.4 FINAL TEST MATERIALS

The pilot study at School A helped consolidate ideas on the clocks to be used in testing. It was decided that the computer was useful for the rapid and efficient presentation of times and that real objects were preferable for setting the time.

The computer programme which randomly selected and stored times and then presented them on the screen, was modified. As before, the next target time was displayed by pressing any key, but the "-" key now caused the programme to move back to the previous time in the cycle, and the "?" key caused a brief display in the corner of screen of the current trial number. Subjects' initials, test number and the target times were stored in a nominated file at start of each run. In order to make use of the frequent periods of the day when subjects were unavailable for interview, a small editor, to input on-site, answers against the target file, was developed.

The format of the digital target times was altered to present four numbers in each case, but the computer analogue clock remained the same. The exact style of both clocks can be seen on the photographs on figure 2.1 and 2.2 respectively.

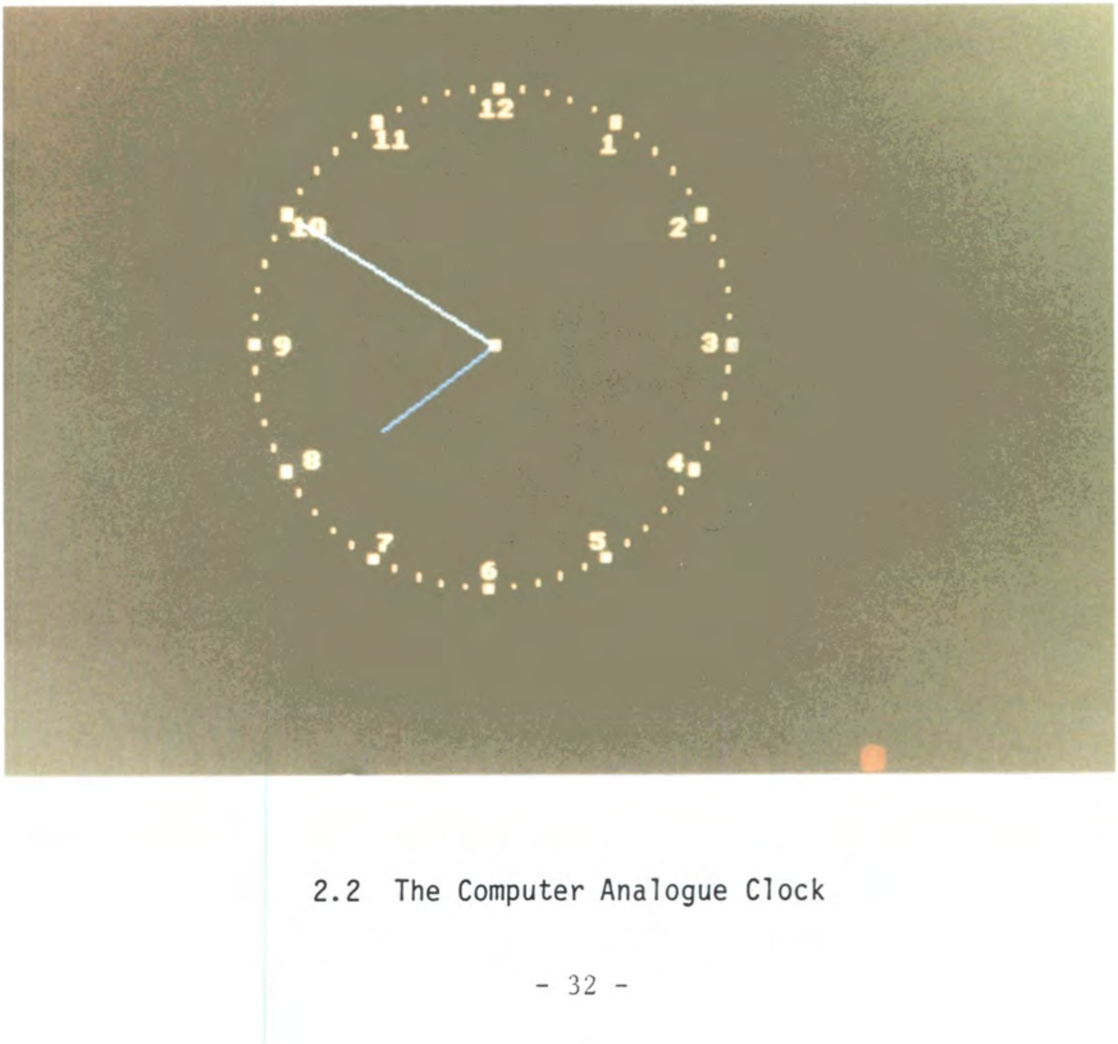
As the digital clock used was unsatisfactory, a digital clock was constructed using a metal board and magnetic numbers. The board held the necessary numbers and there was a small rectangular area marked out, with a colon in the centre. Children set time by moving numbers into this clock. After each time set, the numbers used were removed from the clock and placed back on the board. Spaces were marked in the clock for each of the four numbers, to make placing the numbers in the clock and recording their exact position, easier, though the use of four numbers was not insisted upon. A photograph of the clock is shown on figure 2.3.

This clock did not seem to lead to any marked difficulties. Plastic numerals of about 3 cm in height, with small magnets embedded in their backs were used. Magnetic numerals were attractive because they have the unusual property of being both objects and symbols. They can be moved around, while also being used to represent arithmetical concepts.

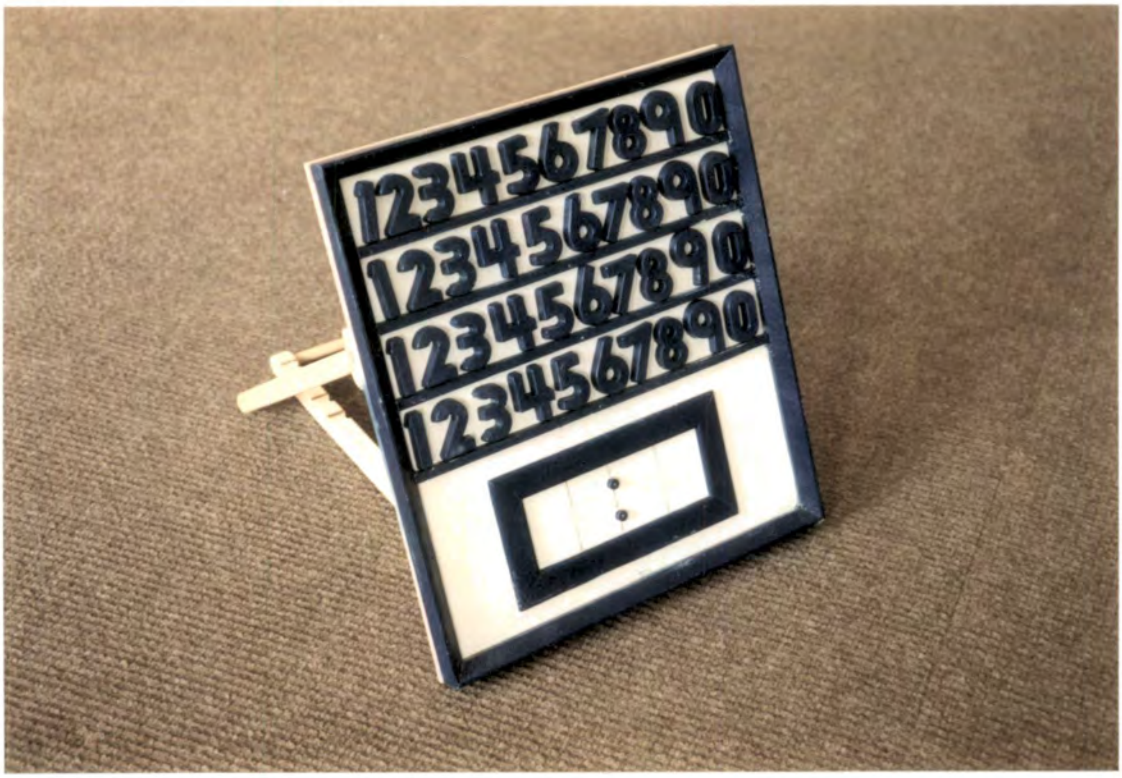
The home-made "real" ungeared analogue clock, as described before, was used. It was reset 12:00 after each time set. The photograph on figure 2.4 shows the analogue clock used.

Blank test record sheets to record responses were used. Also two watches were used, a clear analogue watch with clear numbers and no second hand, and a digital watch without second numbers or a visible date, but simply the hour and minute numbers, separated by a colon.

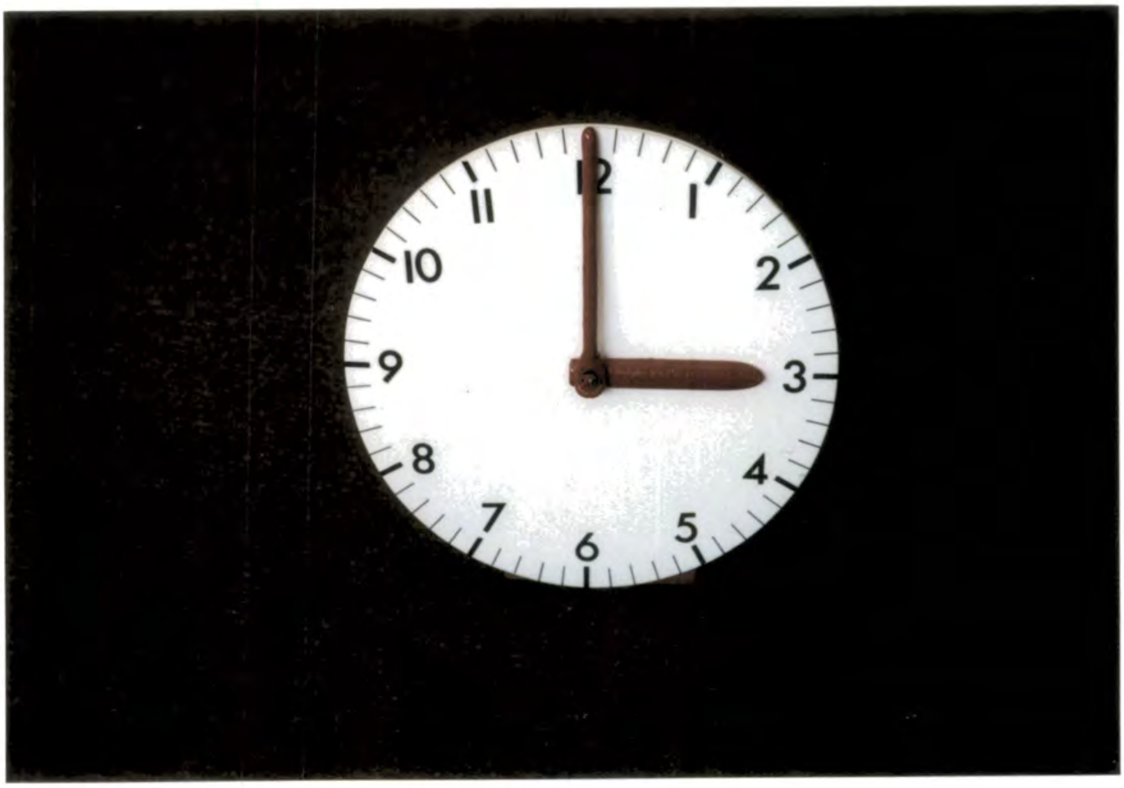
2.1 The Computer Digital Clock



2.2 The Computer Analogue Clock



2.3 The 'Real' Digital Clock



2.4 The 'Real' Analogue Clock

2.5 FINAL TEST PROCEDURE

The general test was used to collect data on children's misconceptions in telling time. Reading questions were generated by the computer, presented on the computer (shown by the pilot study to be as effective a presentation medium as a real clock), recorded by the tester, and later coded by a computer programme. Setting answers were given using real objects.

A corner of the classroom was used as the setting for the experiment as this afforded some degree of quietness whilst still being in familiar surroundings, so minimizing anxiety. A computer was positioned on a trolley so that the screen was directly in front of the subjects' chair to ensure they had a good view of the target times presented, and the keyboard was placed in front of the experimenter to give easy access to the controls. A table of appropriate height was put next to the child's chair, on which the real clocks were placed.

2.5.1 Introduction

Throughout the test, there was no specific wording for the task instructions given to the children, as a relaxed approach was desired. However, the tester was careful to cover the same points with each subject. The tester introduced herself and explained that the study would involve asking subjects some questions about telling the time. It was acknowledged that learning to tell the time is a very difficult thing to accomplish, and the wish to understand what is difficult about it was stated. The interviewer continued by emphasising that this was not a test, and the child did not have to get all the questions right, to try to help reduce anxiety about level of performance. Lastly subjects were instructed to guess if they didn't know the answer, since some needed encouragement, before they would risk failure by giving an answer they were not sure of. A guess was just as valuable as a definite answer in providing some measure of the cognitive processes that children operate in order to make sense of our systems of time representation.

After being given this introduction explaining the purpose of the test and what was required of them, and before the questions on reading and setting time, a small number of questions of a general nature were also asked of the subjects the first time they were tested. These were...

1) Do you have a watch?
2) Do you have a clock in your bedroom?
3) What does the big hand on a watch or a clock tell us?
4) What does the little hand on a watch or a clock tell us?
5) What does the left side of a digital watch or clock tell us?
6) What does the right side of a digital watch or clock tell us?

It was stated that clocks often have two hands, and the children were asked the function of the big and little hands of an analogue clock. They were not shown an analogue clock, as previous experience had shown a tendency to give as answers, the numbers to which the hands were pointing. Answers to questions were recorded on a blank test sheet.

If an answer was not forthcoming, children were encouraged to make a guess, and reminded that their answer did not have to be completely correct. An attempt was made to avoid the response of "Don't know". This policy was pursued throughout the test. The tester also tried to avoid giving feedback about whether questions had been answered correctly, to prevent influencing subsequent responses, unless a child clearly needed encouragement on one or two questions.

Subjects were shown a digital watch and its similarity to the magnetic digital clock was pointed out. The difference stressed was the lack of numbers in the homemade digital clock. Then subjects were asked what each side of a digital watch or clock tells us about (pointing to each side of the magnetic clock in turn). Again children were purposely not shown a working digital watch whilst behind asked the questions, as previous experience had shown a tendency for them to give the particular numbers showing, as answers.

Then the children were asked if they had a watch. Since children often take this as a question about whether they have a watch on at that moment, if they replied in the negative, their response was was checked by asking whether they had a watch at home. Broken watches and those belonging to other people were discounted. If they replied in the affirmative, they were then asked whether it was an analogue or a digital watch, whilst being shown an example of each.

Lastly they were asked whether there was a clock in their bedroom, and if so, whether it resembled the analogue or the digital watch shown to them. Whether the clock belonged to them or not, was not an issue, it was simply important to get an idea of the environment to which they were exposed at home. Clocks which were broken were discounted.

In addition, after each subject had set digital time, questions three and four were repeated, and after each subject had set analogue time, questions one and two were repeated. These questions gave data on consistency as well as enabling answers to be related directly to performance on the test. They also gave some idea of how far limitations of knowledge can exist among children who may have quite good "support" for their learning in terms of "domestic resources".

2.5.2 The Main Test

The final test comprised two sections:- i) reading the time in analogue representation on the computer and setting the equivalent time on an experimental digital clock, ii) reading the time in digital representation on the computer and setting the same time on an ungeared analogue clock.

Ten children were chosen at random from I3, J1, and J2 in each of the four schools 1-4, using a list of random numbers. If any of these were absent, replacements were picked in the same way. Subjects were interviewed twice and alternately received section 1 or section 2 of the test first.

Even numbered subjects were given section I followed by section II, odd numbered subjects were given section II followed by section I. There was an interval of one or two days between the administration of the two sections and this controlled for any effects of day of week, time of day, etc, on the results for each section. In each section there were four questions on the o'clock point, eleven questions on the five minute points, and six questions on the one minute points of the clock.

The programme was started and the subject's details were entered. A blank test record sheet was used to record times read and times set.

2.5.2.1 First Test: Section I

The child was shown the first target time displayed on an analogue clock on the computer screen and asked to identify it. The tester recorded the response on the record sheet. Then the operation of the magnetic digital clock was explained to the child. Again its similarity to a digital watch was stressed, in case this was not obvious to the child. The subject was shown how to use the apparatus by the experimenter moving four separate numbers into the clock. These were then counted and it was stressed that there was room for four numbers, and the child could decide whether to fill the clock up or to leave some empty spaces.

Then the subject was told to move the numbers into the clock to make both clocks, the analogue clock on the computer screen and the magnetic digital clock, say the *same* time. The clocks were pointed out as instructions were given, to ensure that the task was clear. Some encouragement was given at this point irrespective of whether the answer was correct, so that the subject knew that he has done what was required. Then the subject was asked to remove the numbers from the clock and replace them on the board.

For the second question, the experimenter pressed a key so that next target time appeared on the screen. The child was asked to identify the time, and afterwards to move the numbers into the digital clock to make both clocks say the *same* time. Emphasis was placed on making the clocks say the same time to try to limit the influence of the time read on the time set, as an incorrect reading would be more likely to lead to an incorrect setting if the child was simply told to set the time he had read.

This procedure was repeated for all 21 questions of the test. After a few questions, it was often no longer necessary to tell children what to do as they seemed to have got the hang of reading and setting each time presented. However, some children did require continual prompting.

At the end of the test the child was asked again what the left and right sides of the digital clock tell us, as each was pointed to on the magnetic clock. Finally the child was praised for his performance and asked to find the next subject for testing.

2.5.2.2 First Test: Section II

Times were presented on the computer, as described before, this time in digital format, and children were asked to identify the time. Their response was recorded on a blank test record sheet by the experimenter. Then the children were instructed to move the hands on the ungeared analogue clock to make the clock on computer screen and the ungeared analogue clock say the *same* time (each was pointed to in turn to emphasise what was required).

It was necessary to be aware of possibile confusion if the first time a subject was required to set was 12:00, since the hands of the ungeared analogue clock, did not need to be moved from their starting position of 12:00.

After setting each time the child was told to put the hands back to 12. It was necessary to ensure that the child did not move the hands back to 12 before the experimenter had had time to record the time set. Times set were recorded on the test sheet, hour hand then minute hand, both in terms of minutes, thus 4:00, set correctly would be recorded as 20 0.

A key was pressed so that next target time appeared on the computer screen and the child was asked to identify the time. Then he was instructed to move the hands to make both clocks, the digital computer clock and the real ungeared analogue clock, say the SAME time. This procedure was repeated for all 21 questions. Again some children needed to be prompted at each point of the test, whereas others simply proceeded to read and set each time as it was presented.

At the end of the test, the child was asked again to state the functions of the big and little hands of the clock. Then he was praised for his performance and asked to find the next subject.

2.5.2.3 Second Test

The child was greeted and reminded of the previous interview. He was told that he was going to be asked some questions as before, to put him at his ease. Then the 21 questions of the section not yet administered, were asked. These were followed by two questions: if section I had been administered (reading analogue, setting digital time), the function of each side of the digital clock was asked, and if section II had been administered (reading digital, setting analogue time), the function of each of the hands of the analogue clock was asked.

2.6 RELIABILITY STUDIES

Two reliability tests were carried out. The first sought to determine whether the testing procedure developed was sufficiently reliable to allow for generalisation to other investigations concerning time telling. The second was to discover whether subjects' performance on the designed test was affected in any way by the personal characteristics of the tester.

2.6.1 Reliability Of Testing Procedure

2.6.1.1 Method

Twenty children, ten from each of two parallel third year infant classes in School B, were chosen randomly. Half the subjects (five from each class) were tested on section I, then retested on the *same* section two days later. The other ten children were tested on section II, then retested on the *same* section two days later.

2.6.1.2 Results

Figure 2.5 shows the total score for each subject for reading time on the first and second occasions of testing. A Pearson Correlation was carried out on the total correct scores of the twenty subjects reading time (irrespective of whether they read analogue or digital time), for the first and second occasions of testing. The Correlation was 0.95. A Pearson Correlation was carried out on the total correct scores of the ten subjects tested on reading analogue time, for the first and second occasions of testing. The correlation was 0.87. A Pearson Correlation was carried out on the total correct scores of the ten subjects tested on reading digital time, for the first and second occasions of testing. The correlation was 0.97.

Similarly figure 2.6 shows the total score for each subject for setting time on the first and second occasions of testing. A Pearson Correlation was carried out on the total correct scores of the twenty subjects setting time (irrespective of whether they set analogue or digital time), for the first and second occasions of testing. The Correlation was 0.93. A Pearson Correlation was carried out on the total correct scores of the ten subjects tested on setting digital time, for the first and second occasions of testing. The correlation was 0.86. A Pearson Correlation was carried out on the total correct scores of the ten subjects tested on setting analogue time, for the first and second occasions of testing. The correlation was 0.94.

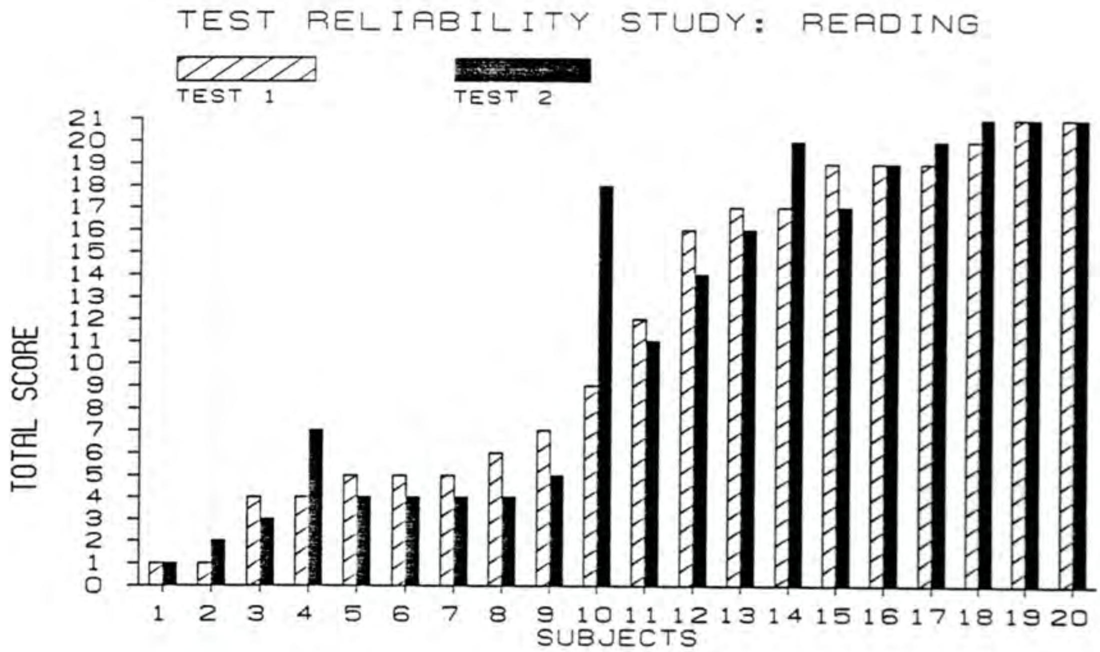
2.6.1.3 Conclusions

The high correlations obtained indicated that the test has good reliability. It was therefore concluded to be a feasabile testing procedure for other workers in this area.

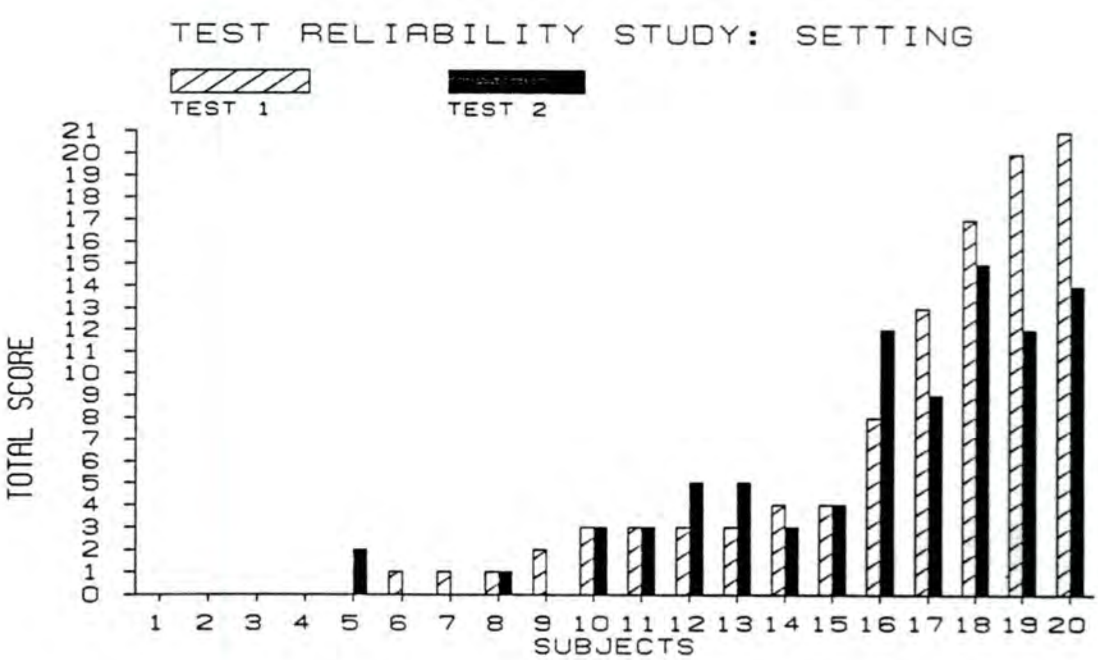
2.6.2 Reliability Of Tester

2.6.2.1 Method

Twenty pupils chosen randomly from the J1 class at School B were used as subjects. There were two testers, the experimenter (tester B), and another (tester A). On the first day tester A administered the test to subjects 1-10. On the second day, tester B administered the test to subjects 11-20 and gave a second test to subjects 1-10. On the third day, tester A gave a second test to subjects 11-20. Odd numbered


TEST RELIABILITY STUDY: READING
TEST 1
TEST 2
TOTAL SCORE
SUBJECTS
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21

2.5


TEST RELIABILITY STUDY: SETTING
TEST 1
TEST 2
TOTAL SCORE
SUBJECTS
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21

2.6

subjects were tested first on section I then section II, whereas even numbered subjects were tested the other way around.

Thus each subject was tested twice, once by each tester, with a break of one day between the two occasions of testing. Half the subjects were tested first by tester A, and half the subjects were tested first by tester B.

2.6.2.2 Results

The results from the two testers were compared to consider the effect of experimenter characteristics on performance of subjects. Figure 2.7 shows the total score for each subject for reading time when tested by tester A, and by tester B. A Pearson Correlation was carried out on the total correct scores of the twenty subjects reading time (irrespective of whether they read analogue or digital time), when tested by each of the testers. The Correlation was 0.81.

A T test was carried out to compare total scores obtained by pupils tested by tester A with those tested by tester B. It proved to be non-significant.

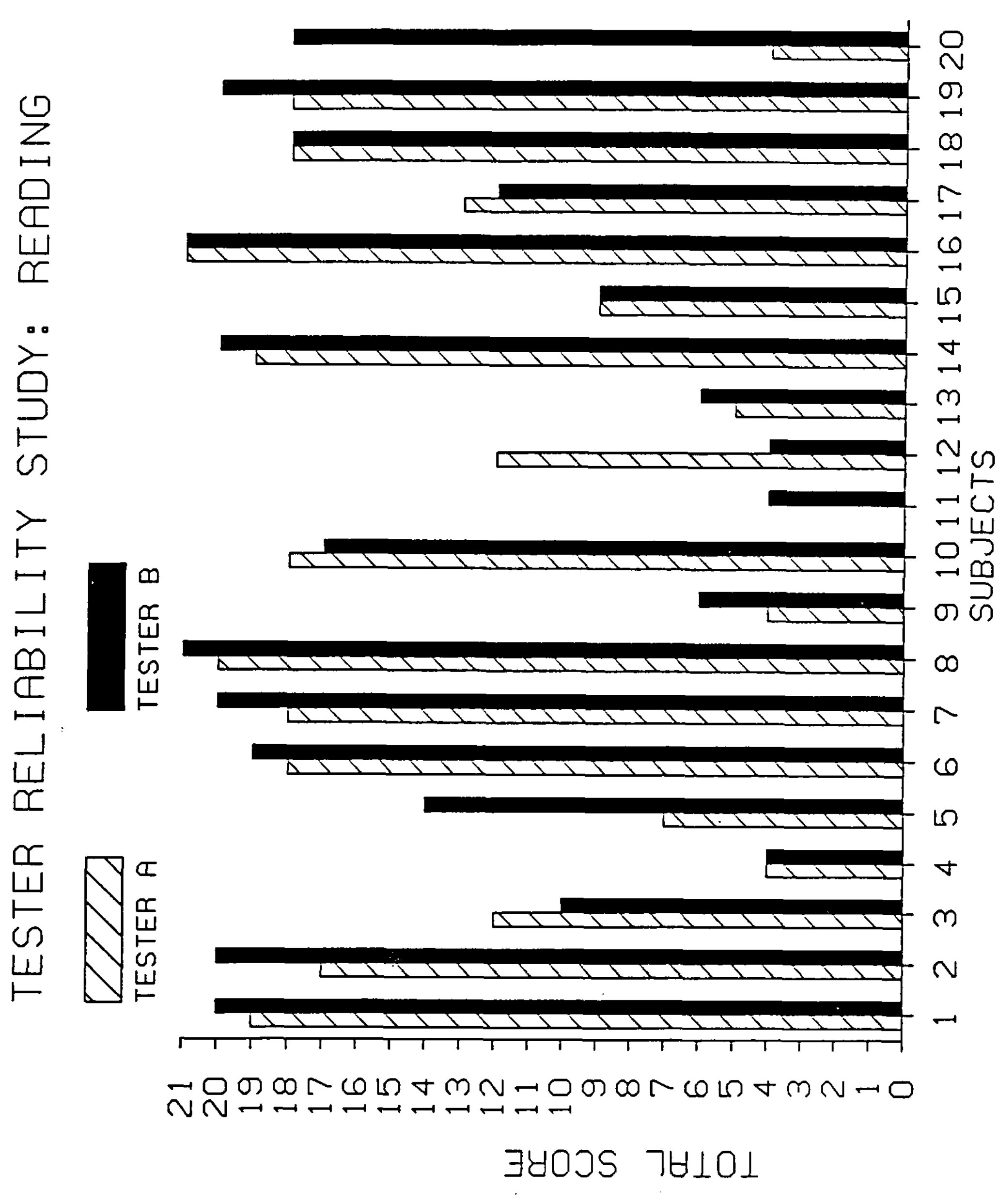
2.6.2.3 Conclusions

The high correlation, together with the non-significance of the T test, showed that there was no systematic difference between the scores obtained by children when tested by tester A and those obtained when tested by tester B. Therefore it was concluded that the data gathered from the test as a whole, was not biased in any way by characteristics of the experimenter.

2.7 MEASURES OBTAINED

Once the test procedure and materials had been finalised and reliability had been proved, the main test was administered.

Questions were generated and recorded by the computer programme, and presented on the computer. Answers were recorded on paper by the tester. An example of a completed test record sheet is given in


TESTER RELIABILITY STUDY: READING
TESTER A
TESTER B
TOTAL SCORE
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
SUBJECTS

2.7

appendix I. Data for one hundred and twenty subjects was obtained.

The class teachers of the subjects were informally interviewed at length, usually in the staffroom, with a standard set of questions in order to gain some insight into what the child has been exposed to in respect of time, and in what manner. This list of questions can be seen in appendix II. Data was obtained from ten teachers, as one teacher was responsible for both infant 3 and junior 1 children and another teacher was unfortunately unavailable for discussion.

There was also an informal discussion with the school mathematics co-ordinator in order to determine the place of mathematics within the school. The prepared list of questions can be seen in appendix III. Data was obtained from the specialist in each of the four schools.

Lastly a review was made of some of the important features of primary software on time, with the intention of making some general evaluative comments about this type of resource, its content, availability and use. An additional aim was to offer suggestions as to how programmes can be better fitted to the cognitive abilities and learning strategies of young children. Appendix VIII shows a list of all relevant software encountered, Appendix IX summarizes its content and availability, and a review of software is presented in Appendix X.

2.8 TREATMENT OF DATA

The test questions, automatically stored on disc at the time of testing, were transferred to computer files. There was a separate file for each school. Subjects were recorded with respect to school, class, subject number, initials, and test number. In addition a separate file containing details of full name, experimental condition, date of birth, and sex for each subject, was available for reference purposes.

Then the time read and the time set for each time presented, was added to the database files from the test record sheets, so that for each subject there were two sections of twenty one questions, each with a corresponding reading and setting answer. A system of recording the subjects' reponses on the data files was devised whereby there were discrete columns for each unit of the response - number, qualification, conjunction, number, qualification. An hour or minute number read, can be qualified with "hours", "minutes" or "o'clock", or not qualified at all. Conjunctions used to join the two parts of an answer, can be "and", "past", and "to", sometimes a conjunction is omitted. Examples include "3 hours and 5 minutes", and "9 to 12". Thus the information was easy to read, and this helped simplify the analysis.

Each response was marked as correct or incorrect by a computer programme written specifically for this purpose. The criteria on which this distinction was made were straightforward for reading time. However for setting time, because of the difficulty of setting the hour hand exactly correctly, even for adults, strict and lax criteria were specified for analogue time. The same was done for digital time, using place value as the differing factor. Times marked under strict criteria had to be completely correct before they were marked as correct, but lax criteria allowed certain concessions.

Analogue Strict Criteria: The hour hand must be set exactly on the correct position. For example, if the time is 7:20, the position of the hour hand would be accepted as correct if it was one minute past the hour numeral 7, ie. at 36 minutes past the hour. This is because the hour hand moves one minute for every twelve minutes of the minute hand.

Analogue Lax Criteria: The hour hand is marked as correct if it points directly at the hour number of the target time, or at any of the four subsequent minute points, but not at the following hour number. Thus in the above example, the hour hand would be accepted as correct if it was positioned on 35, 36, 37, 38 or 39 minutes past, but not on 40 minutes past, ie. the hour numeral 8.

Digital Strict Criteria: All digits must be placed in the correct position with respect to the colon, although a nought infront of a single digit was not an essential requirement. For example, if the target time was 7:30, only "7:30" or "07:30" would be acceptable.

Digital Lax Criteria: Place value errors were allowed, The rule is not simply that a space can be taken as 0, but that, if the answer is incorrect, a space can be swopped with its accompanying number on that side of the colon, and a 0 substituted for it to see if it is now correct. For example, " 5:4 " would be allowed for 05:04, but " 5:40" would not, and "5:45" would be allowed as correcct for 5:45, but "50:45" would not. Also 12: would be allowed for 12:00, thus two spaces on the right of the colon can be taken as 00.

2.9 THE CODING SYSTEM

From experience gained of the types of errors children made in the test, it was recognised that each of the four possible conditions (reading analogue, reading digital, setting analogue, setting digital) would require a different coding system. Also, for both the read time and the set time, the response should be marked and coded with respect to the given time, since when the children were asked to set the time, they were specifically told to "make both clocks say the *same* time". There are still problems with this approach as children often read the time incorrectly, which makes the chances of subsequently setting the time correctly, very unlikely. For this reason, there would also be benefits in analysing time set with repect to time read. However, the approach chosen seemed to be the best way to address the inherent difficulty of measuring setting time, which is a two stage process, dependent on the ability to read time.

Due to pressures of time, only a system for coding the errors children make in reading the time was developed. Before any attempt at the production of a computer coding system was made, the possible types of misunderstandings were distinguished. For analogue time these are - hand confusions, metric confusions, past/to confusions, and computational errors. For digital time these comprise - side of clock confusions, reversal of hour and minute numbers, reveral of digits and place value confusions, and reading digit confusions. These are further outlined for analogue time, in appendix IV.

This coding system is presented as a workable approach to the daunting task of capturing the processes involved as children learn to read analogue time. However it is beyond the scope of this study to code errors in the other three conditions tested. It is hoped that the analysis of the collected data will lead to a considerable increase in our understanding of how children master the skill of telling time, and will highlight the features of reading analogue time that are conceptually difficult for young children to learn. Because of the complexity of the errors children make in telling the time, it is not an easy task to develop a coding scheme that is comprehensive and about which one can feel absolutely confident, it is only possible to aim for a good approximation.

In the output of the computer coding there are four coding areas. These are for a) an overall right/wrong judement, b) a judgement on the conjunction of the hour and minute numbers, c) an hour number judgement, and d) a minute number judgement. Area a) has only one space. This is either filled with an "X" if the time read is incorrect, or is left blank if the response is correct. Area b) has two coding spaces, the first is for a code to show incorrect use of "past" or "to" and the second shows incorrect use of the nearest or further hour number.

Area c) has two spaces. The first is either filled with an "x" if the hour number read is incorrect, or is left blank if the response is correct. The remaining space is for codes which describe the nature of the error. Area d) has eight spaces. The first is either filled with an "x" if the minute number read is incorrect, or is left blank if the response is correct. The remaining seven spaces are for codes which describe the nature of the error.

The computer programme specified to code reading analogue time, consisted of a number of steps, as follows. An example of coded data can be seen in appendix V.

1) Marking: The time read and the time given are compared to see whether an error was made or not.

If the answer is correct, the first coding area is left blank, and the coding process stops.

If the answer is incorrect, the first coding area is marked with an "X" and the coding process continues as follows...

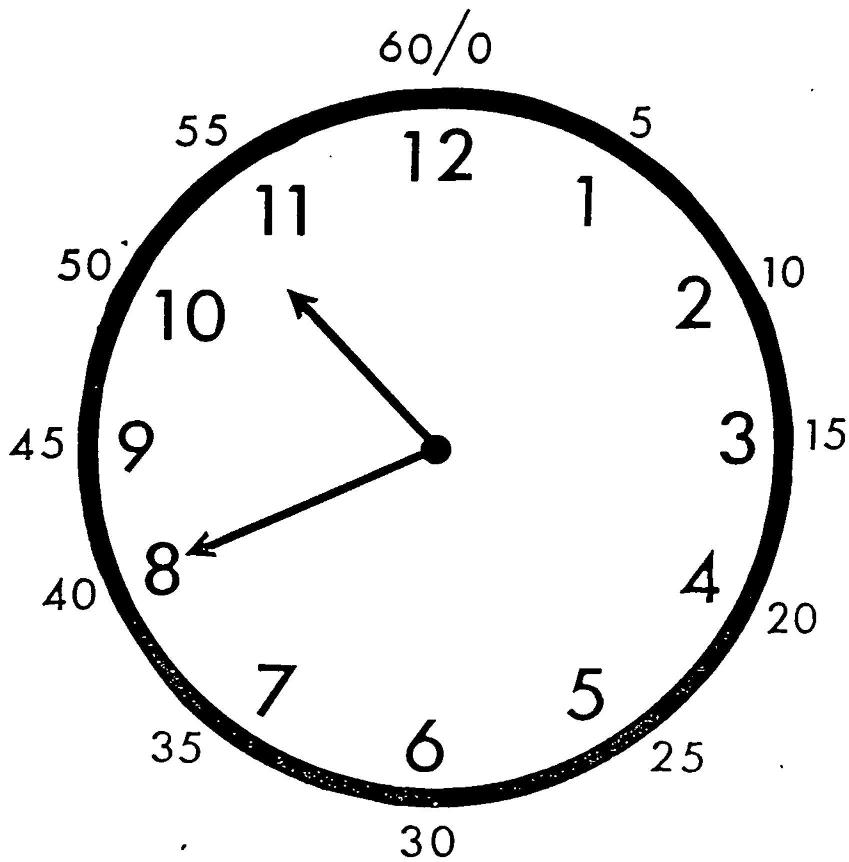
2) Differentiation of the two parts of the response: Which part of the response is the minute section and which is the hour, is determined through examination of the conjunction and qualifications used. If this leaves the matter unresolved, the first number is assumed to be the hour section, and the second, the minute section.

3) Response Minute Number, Use of Hand and Metric: First it is determined whether there is a response minute number. If there is not, an "x" is placed in the first space of area d) to denote an incorrect answer, and an "0" is placed in the second space to denote the ommission of a minute response. If there is a response minute number, the target time is taken, and from this, 8 possible numbers are generated. bearing in mind that the child can count "minutes to" or "minutes past" the hour, in either metric and using either hand.

If the minute hand and the minute metric are used, possible numbers are 40 and 20, if the minute hand and the hour metric are used, possible numbers are 8 and 4. If the hour hand and the minute metric are used, possible numbers are 53 and 7, and if the hour hand and hour metric are used, possible numbers are 11 and 1. A summary of the numbers derived in this case is given in figure 2.8.

An attempt is made to match the minute number of the response to one of these 8 possible numbers. If there is an unambiguous correspondence with either of the possible numbers derived from the minute metric and the minute hand (ie. 40 or 20), then the minute response number is correct and the first coding space of area d) is simply left blank. If there is an unambiguous correspondence with any other possible numbers, then the minute number of the response is coded firstly as incorrect (ie. "x"), in the first coding space, and secondly with respect to the error found. In this example, the numbers 53 or 7 would generate a code of "R" in the second coding space to denote use of the wrong hand, the numbers 8 or 4 would generate a code of "M" in the third coding space to denote use of the incorrect metric, and the

TARGET TIME



		METRIC	
		MINUTE	HOUR
HAND	MINUTE	40 / 20	8 / 4
	HOUR	53 / 7	11 / 1

2.8 Possible Minute Response Numbers

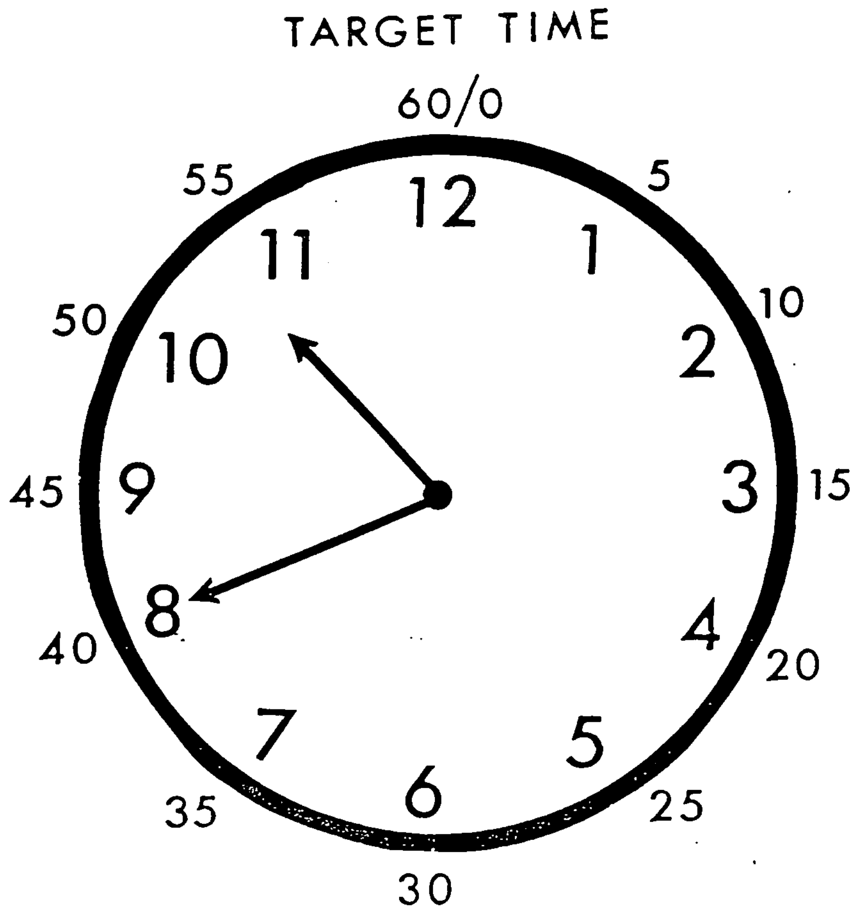
numbers 11 or 1 would generate a code of "HM" in the second and third coding spaces to denote a combination of these two errors.

If any of the possible numbers generated are identical to each other, then if the response number matches this number, its derivation is ambiguous and will be coded with an "a" in the second coding space. This is flagged by a mark to the right of all the coding areas, as manual coding will be necessary to attempt to resolve the ambiguity.

Whatever the outcome of the coding of the response minute number, the next step followed is always...

4) Response Hour Number, Use Of Hand And Metric: First it is determined whether there is a response hour number. If there is not, an "x" is placed in the first space of area c) to denote an incorrect answer, and an "0" is placed in the second space to denote the ommission of an hour response. If there is a response hour number, the same process of coding occurs for the hour number of the response, except that in this case, there are only five possible numbers. If the hour hand and the hour metric are used, possible numbers are 10 or 11, if the hour hand and the minute metric are used, the possible number is 53. If the minute hand and the hour metric are used, the possible number is 8, and if the minute hand and the minute metric are used, the possible number is 40. A summary of the numbers derived in this case is given in figure 2.9.

Again unambiguous correspondence of the hour response number with the possible numbers derived from the hour hand and the hour metric (ie 10 or 11), results in no code in the first coding space of area c), as the hour response number is correct. However unambiguous correspondence with any of the other three possible numbers results in a code of incorrect (ie. "x"), in the first coding space, and a further code describing the nature of the error. A response of 8 would be coded as "R" in the second coding space, to denote the use of the wrong hand, a response of 53 would be coded as "M" in the third coding space to denote the use of the wrong hand, and a response of 40 would be coded as "HM" in the second and third coding spaces to denote a combination of these two errors.



		METRIC	
		HOUR	MINUTE
HAND	HOUR	10 / 11	53
	MINUTE	8	40

2.9 Possible Hour Response Numbers

If any of the possible numbers generated are identical to each other, then if the response number matches this number, its derivation is ambiguous and will be coded with an "a" in the second coding space. This is flagged by a mark to the far right of all the coding areas, as manual coding will be necessary to attempt to resolve the ambiguity.

5) Then ONE of the following procedures is followed...

a) If Both The Minute And The Hour Response Number Has Been Coded As Correct (yet the programme has coded the overall answer as wrong): The only remaining possible source of the error is a confusion between "past" and "to". Therefore a check for the exact nature of this confusion is carried out. If the conjunction "past" has been used instead of "to", then a code of "P" is recorded at the start of the whole coding area. If the conjunction "to" has been used instead of "past", then a code of "T" is recorded in the first space of area b).

The second phase of the past/to analysis concerns the hour numbers chosen. If the hour nearest the hour hand has been used to generate the hour number, a code of "N" is placed in the second space of area b), and if the further hour number has been used, a code of "F" is used, and this is qualified with a "p" or "t" depending on the conjunction used.

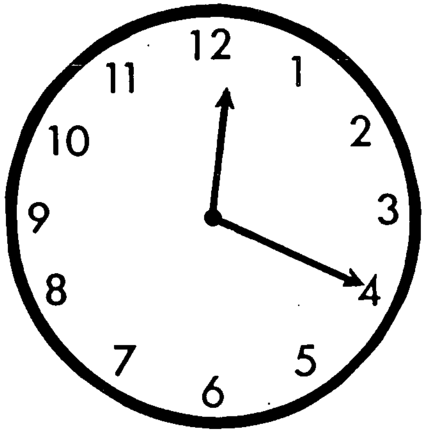
The possible past/to misunderstandings that can occur, and the codes that have been attributed to them, are detailed on figure 2.10.

b) If The Hour Response Number Only Has Been Coded As Incorrect: No further coding takes place, but a mark is put to the right of all the coding areas to flag the fact that although a coding decision has not been possible, there is an error which manual coding should attempt to define.

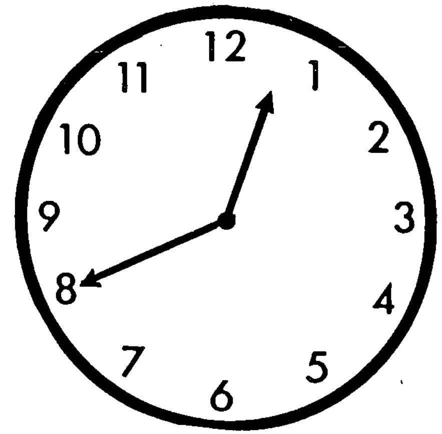
c) If The Minute Response Number Only Has Been Coded As Incorrect: ALL the following types of errors are checked for...

i) Fractions: If the minute response given is "o'clock", "half past" or "quarter past", it is coded simply as "o", "h" or "q" respectively, in the fourth coding space.

TARGET
12:20



TARGET
12:40



RESPONSE	CODE	EXPLANATION
20 past 12		Correct
20 past 1	.Fp	Incorrect use of further hour
20 to 12	T.	Used "to" instead of "past"
20 to 1	TF	Used "to" instead of "past" and incorrect use of further hour
40 past 12	PN	Used "past" instead of "to" and incorrect use of nearer hour
40 past 1	P.	Used "past" instead of "to"
40 to 12	.Nt	Incorrect use of nearer hour
40 to 8		Correct

RESPONSE	CODE	EXPLANATION
40 past 12		Correct
40 past 1	.Np	Incorrect use of nearer hour
40 to 12	T.	Used "to" instead of "past"
40 to 1	TN	Used "to" instead of "past" and incorrect use of nearer hour
20 past 12	PF	Used "past" instead of "to" and incorrect use of further hour
20 past 1	P.	Used "past" instead of "to"
20 to 12	.Ft	Incorrect use of further hour
20 to 1		Correct

2.10 Past/To Misunderstandings and their Codes

ii) Computational Error: The minute response number is checked for computational errors of between one and five minutes. If a computational error is found, it is coded as "1", "2", "3", "4", or "5" in the sixth coding space.

iii) Reversed Hands AND Computational Error: The minute response number is checked for a combination of hand reversal and computational error. If such errors are found they are coded as "R1", "R2", "R3", "R4", or "R5" in the seventh and eighth coding spaces.

iv) Hour Metric X10: The minute response number is checked to see if it is derived from the use of the hour metric multiplied by a factor of ten.

If two possible causes of the error have been found, they are placed to the right of all the coding areas, and flagged by a mark. A different mark is made if more than two, or no causes of the error have been found.

2.10 FEEDBACK TO TEACHERS

Feedback to teachers consisted of two types of data, summary data and raw data. The raw data was rather detailed and was provided only in case a teacher should want to look specifically at the types of errors that her pupils were making, or at the kind of vocabulary they were using to read time.

The summary data comprised information on total scores and consisted of separate sheet of data for each of the following six aspects of the test - reading analogue time, reading digital time, setting analogue time (marked according to lax criteria), setting digital time (lax criteria), setting analogue time (strict criteria), setting digital time (strict criteria).

The sheets showed whether each five minute question had been answered correctly or incorrectly by each subject, for the three classes in a school, separately. Total score, o'clock score, and one minute score were also given, and the pupils within a class were ranked by total score.

Appendix VI shows an example of the information teachers were given. Later teachers were given a summary of the findings, conclusions and recommendations of the study.

CHAPTER 3: RESULTS

The statistical analysis applied to the data involved either a Student T test when two variables were compared, or a multi factor analysis of variance treating the independent variables as fixed effects.

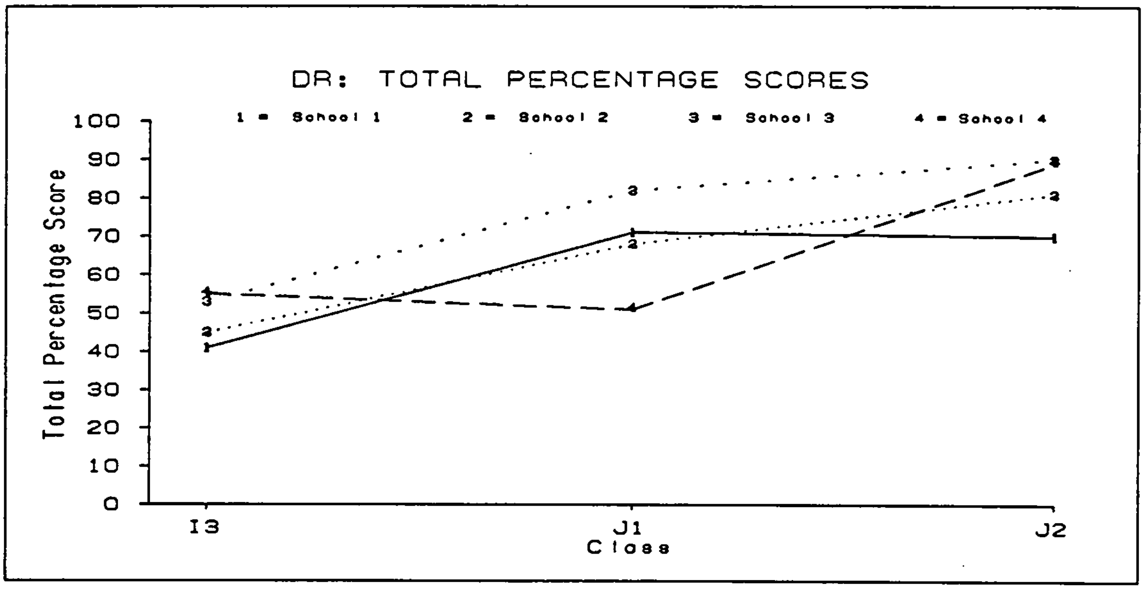
3.1 TEST PERFORMANCE

3.1.1 Overall Test Performance In Reading Digital Time

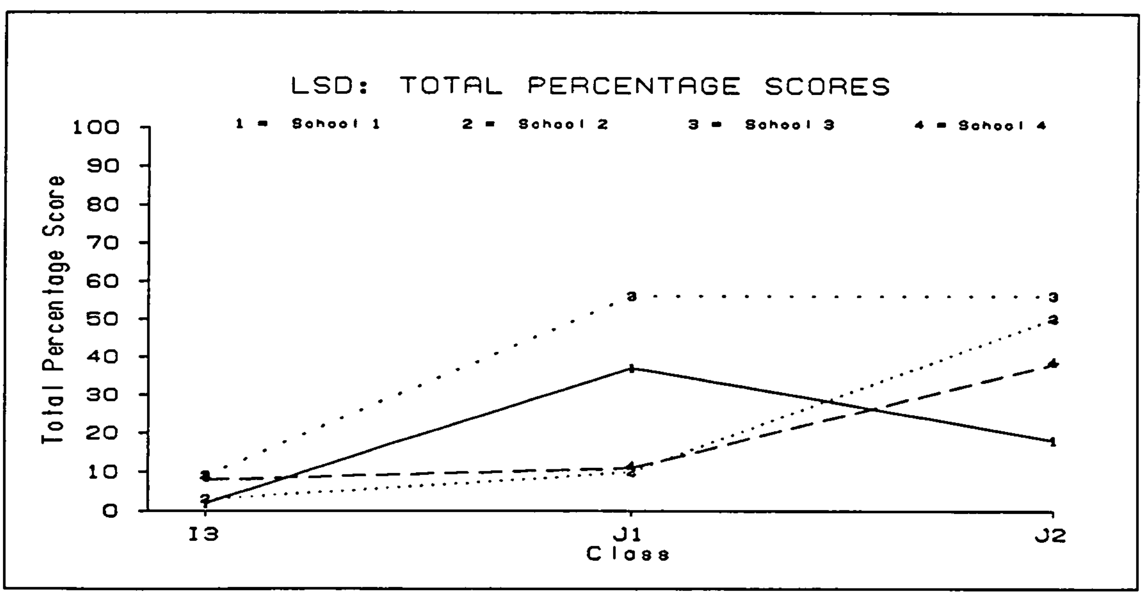
Figure 3.1 shows the total percentage score for reading digital time, for each class, by school. Level of performance is not as high as might be expected considering the apparently simple nature of reading digital time. The infant children answer about half of the questions correctly, the first year juniors average around 70% and by the second year of junior school children are able to attain an average of around 80% correct responses. The means for the classes in ascending order of age are 10.23, 14.35 and 17.33, out of 21 questions. Thus there is a strong overall effect of age, $F(2,108) = 12.10$ ($p<.001$).

To probe a little further into understanding of digital time, children were also asked to set digital time by transferring information from an analogue clock. Clearly children's performance in setting digital time is not independent of that of reading analogue time and must be viewed with this in mind. However, there is some useful information which can be gained from looking at children's performance when asked to set digital time. Setting responses obtained were marked according to lax and strict criteria, the difference being that in the former case allowances were made for place value confusions.

Figure 3.2 shows the total percentage scores for setting digital time marked according to lax criteria. The most striking feature of the data is the enormous reduction in performance level for setting digital time in comparison with reading digital time. In fact scores for the infant subjects range from only (2% to 9%). The means for infants, first and second year juniors were 1.13, 5.98 and 8.53, respectively. There was a significant class effect $F(2,108) = 20.83$ ($p<.001$), school effect $F(3,108) = 5.16$ ($p<.001$), and interaction effect $F(6,108) = 3.72$.



3.1 Graph of Total Percentage Scores for Reading Digital Time



3.2 Graph of Total Percentage Scores for setting Digital Time
(Marked According to Lax Criteria)

It must be remembered that performance on setting digital time is reliant on ability to read analogue time. In spite of this constraint, the data do seem to indicate that children have much lower levels of understanding about digital time than the reading data alone suggests.

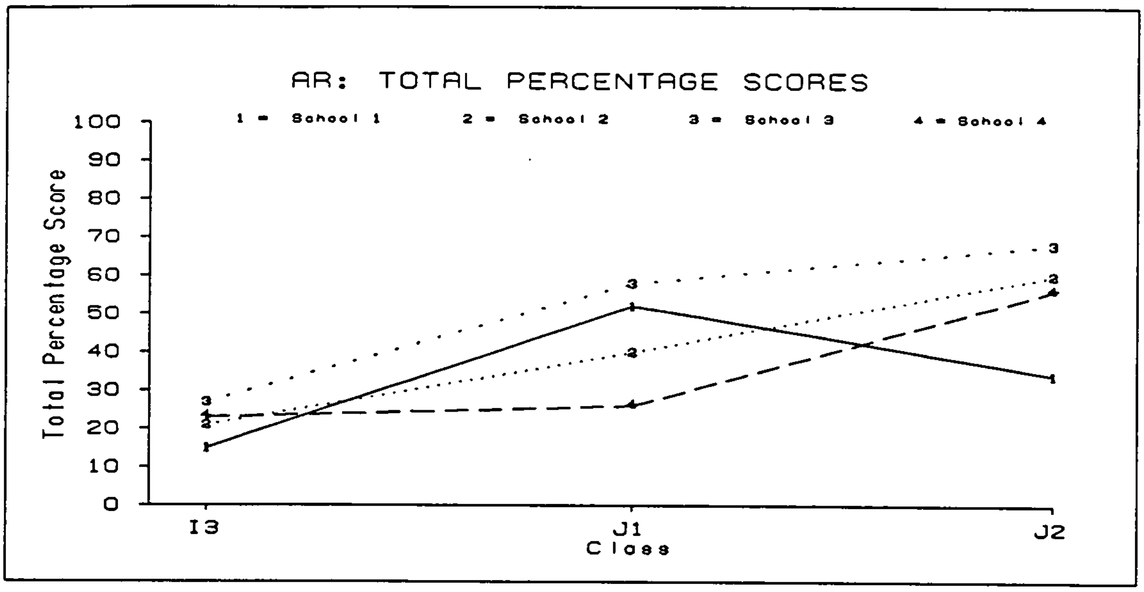
3.1.2 Overall Test Performance In Reading Analogue Time

Figure 3.3 shows total percentage scores for reading analogue time, displayed for each class, by school. The most striking feature of the data is the generally poor performance of subjects. The youngest children are averaging only around a fifth of the test correct, by the next year this has gone up to an average of around 40%, and by the oldest class examined, children are still only getting about half of the test correct. The means for the three classes were 4.53, 9.25 and 11.48 respectively, out of the 21 test questions. There is an increase in total score for reading analogue time, with age. This is significant effect, $F(2,108) = 21.51$ ($p<.001$). There is also a significant school effect $F(3,108) = 78.37$ ($p<.05$) and an interaction effect between class and school $F(6,108) = 57.09$ ($p<.05$). The interaction is caused by the J1/J2 inversion in School 1.

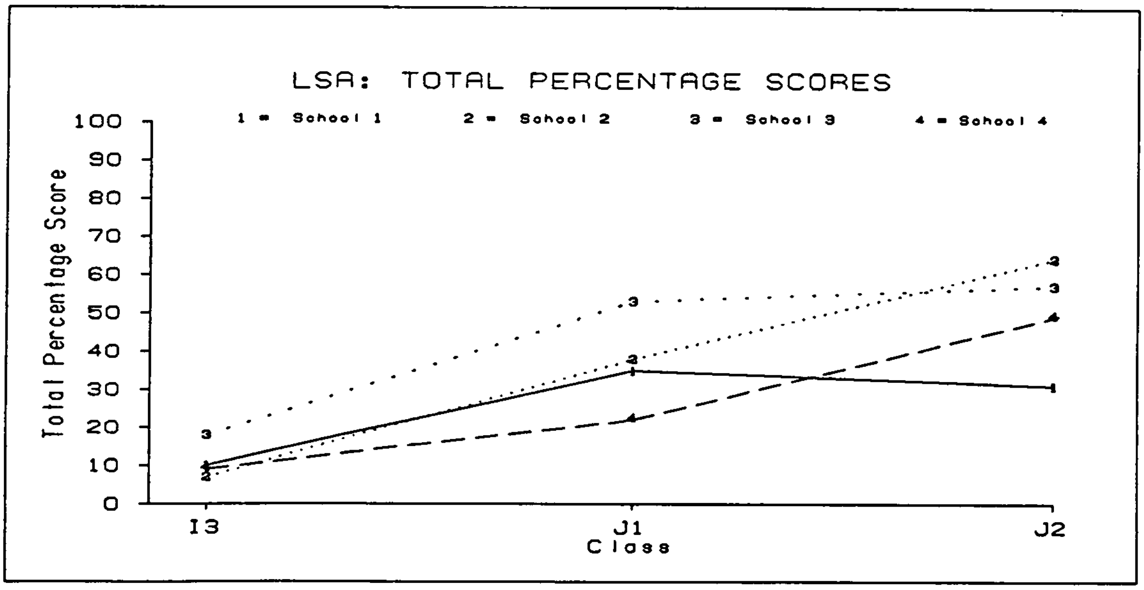
Again by considering subjects' ability to set time, additional information concerning their understanding of the time representation as a whole can be gained. Figure 3.4 shows the total percentage scores for setting analogue time, marked according to lax criteria, which allowed for imprecise setting of the hour hand.

There is a marked reduction in scores for analogue setting (lax) over those for analogue reading, even the most able subjects score only around 60% correct. The mean scores for infants, first, and second year juniors were 2.3, 7.8, and 10.53 respectively. A significant class effect $F(2,108) = 28.10$ ($p<.001$), school effect $F(3,108) = 3.62$ ($p<.05$), and interaction effect $F(6,108) = 1.59$ ($p<.001$) was found.

Since the stimulus for setting analogue time was a digital clock, performance on setting analogue time is partially dependent on that for reading digital time. In spite of this, subjects' performance on setting analogue time suggests that they are less knowledgeable about the analogue clock than would be realised from an examination of the



3.3 Graph of Total Percentage Scores for Reading Analogue Time



3.4 Graph of Total Percentage Scores for Setting Analogue Time (Marked According to Lax Criteria) ability to read analogue time alone.

3.1.3 Conclusion

From the data collected on reading both digital and analogue time, it can be seen that children experience considerable difficulties in decoding the information contained within these representational systems. Considering that telling the time is a skill thought to be almost complete by the age of 7 or 8 years, by many educators, the low level of the scores is particularly serious.

A further examination of the ways in which the information carried by these clocks is more or less difficult to decode will highlight characteristics of the learning processes that are occurring. Digital and analogue representations are approached separately since intuitively they are likely to require different types of skills, and considerable differences in performance to them have already been documented.

3.2 DIFFICULTIES IN PROCESSING THE DIGITAL REPRESENTATION OF TIME

3.2.1 The Nature Of The Acquisition Of Digital Time Telling Skills

The first issue which must be addressed in an examination of response to digital time is the nature of the development of the ability to identify time in this form. Whether development is a relatively sudden process, whereby a class of subjects tends to be dichotomized, with some children who have access to the necessary principles and others who do not, or whether it is a more gradual process of learning through practice, must be clarified.

The idea of sudden access to the skill predicts a bimodal frequency distribution of scores, with some subjects scoring low and others scoring high, but few subjects falling between these these two categories. On the other hand, a gradual acquisition of the skill would predict that scores would be relatively evenly distributed over the possible spectrum.

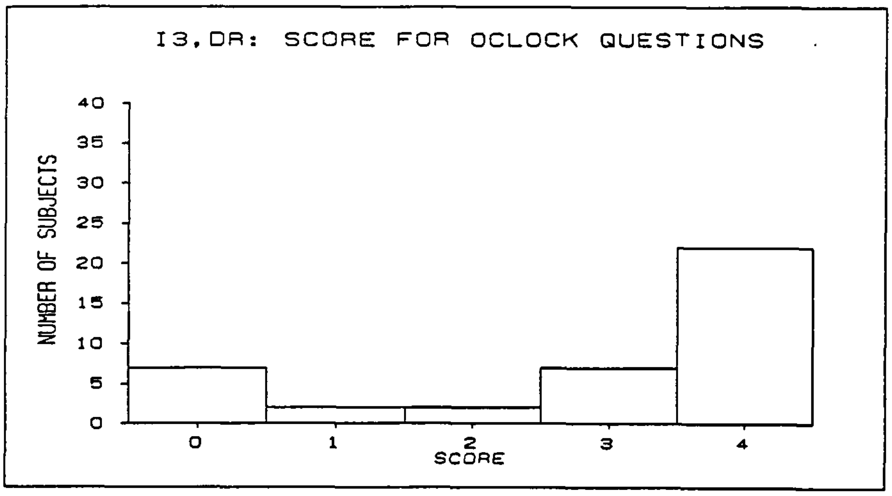
It is difficult to consider this question with regard to the o'clock questions as the subjects involved in this study had largely all mastered the identification of digital time on the o'clock point, as can be seen from figures 3.5-3.7 which show the number of subjects in each of the three year groups who attained each possible score from nought to four, on the o'clock questions. Although the majority of subjects are attaining the maximum score, the remaining subjects are distributed reasonably evenly across the other possible scores.

The issue is more relevant to the performance of subjects on the five and the one minute questions. Figures 3.8-3.10 show how subjects scored on the five minute questions, at each age level.

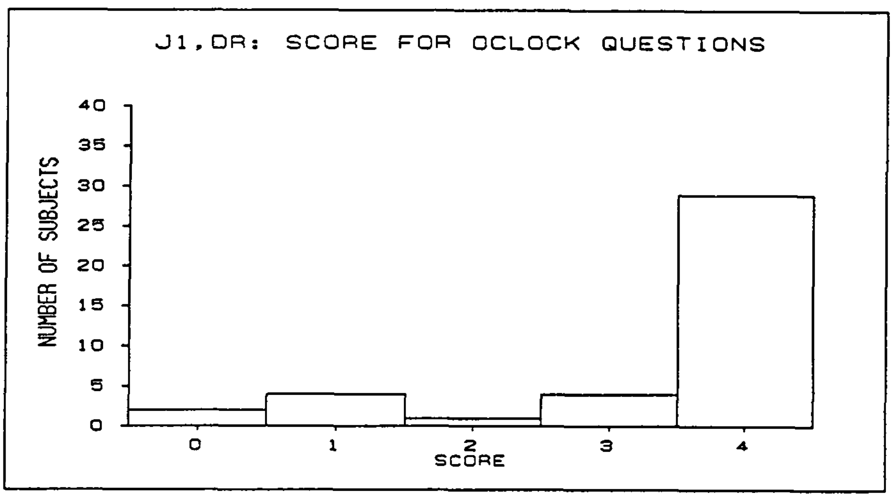
The predominant indication from this data is that the acquisition of the skills involved in reading digital time to the five minute point is a gradual process, since subjects in each year group are well distributed across the spectrum of possible scores. When the pattern of scores for the three age groups is taken together, there is some slight indication of bimodality, since a large number of subjects in I3 score nought, and a larger number of subjects in the two older groups score particularly well, however the effect is small and does not detract from the overall picture of a gradual acquisition of these skills.

In looking at the distribution of subjects across possible scores in response to reading digital time to the one minute point, (figures 3.11-3.13), it can be seen that a very similar pattern is obtained. Again the subjects for each class are well distributed over the possible scores, so that there is no doubt that the development of ability to tell digital time to the one minute point is also a gradual process. However, the bimodality observed with respect to reading digital time to the five minute point, is seen in this case also, with a considerable number of the younger children scoring zero and the scores for the older children clustered towards the higher end of the spectrum.

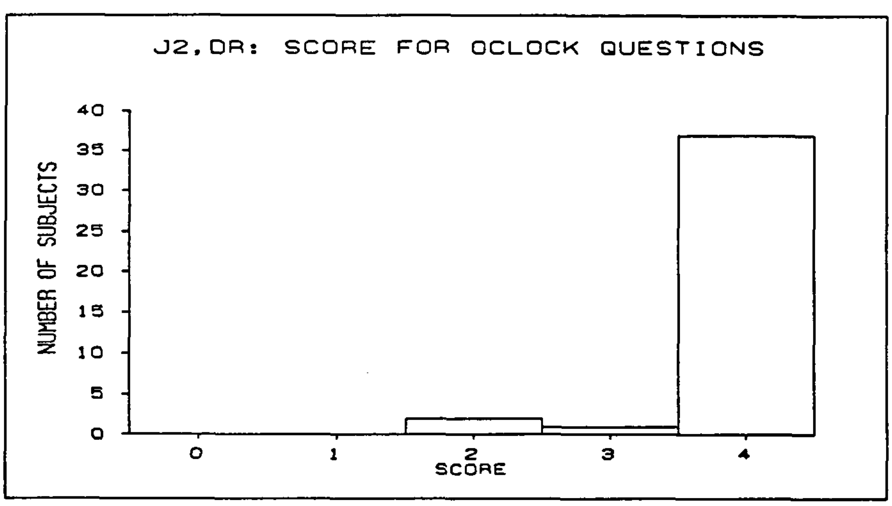
Thus the acquisition of the skills required to tell digital time to the five and one minute points is a gradual process which develops


I3,DR: SCORE FOR OCLOCK QUESTIONS
NUMBER OF SUBJECTS
40
35
30
25
20
15
10
5
0
0
1
2
3
4
SCORE

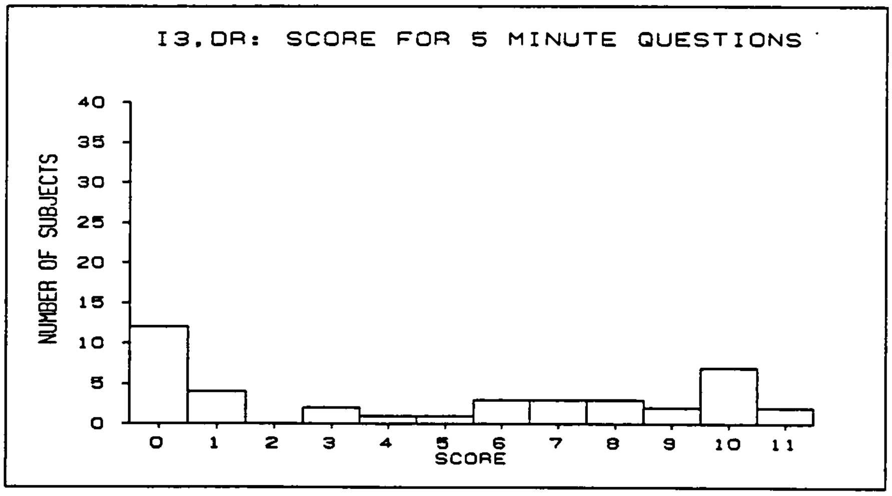
3.5


J1,DR: SCORE FOR OCLOCK QUESTIONS
NUMBER OF SUBJECTS
40
35
30
25
20
15
10
5
0
0
1
2
3
4
SCORE

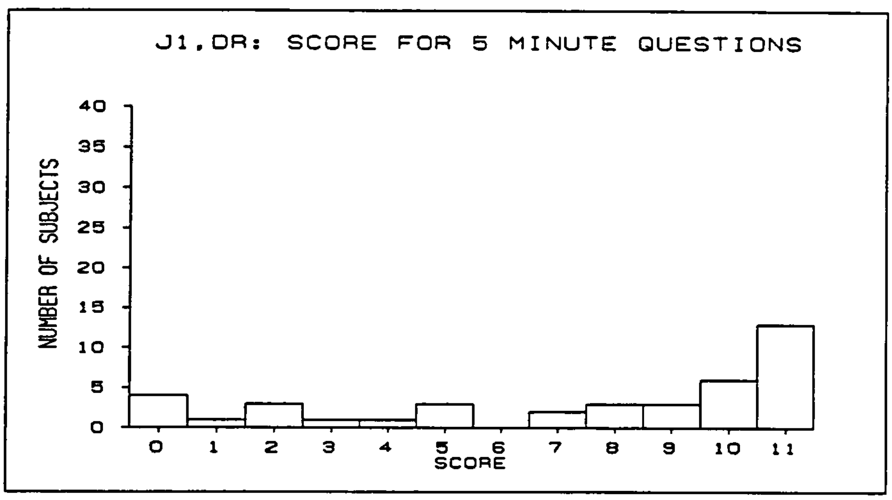
3.6


J2,DR: SCORE FOR OCLOCK QUESTIONS
NUMBER OF SUBJECTS
40
35
30
25
20
15
10
5
0
0
1
2
3
4
SCORE

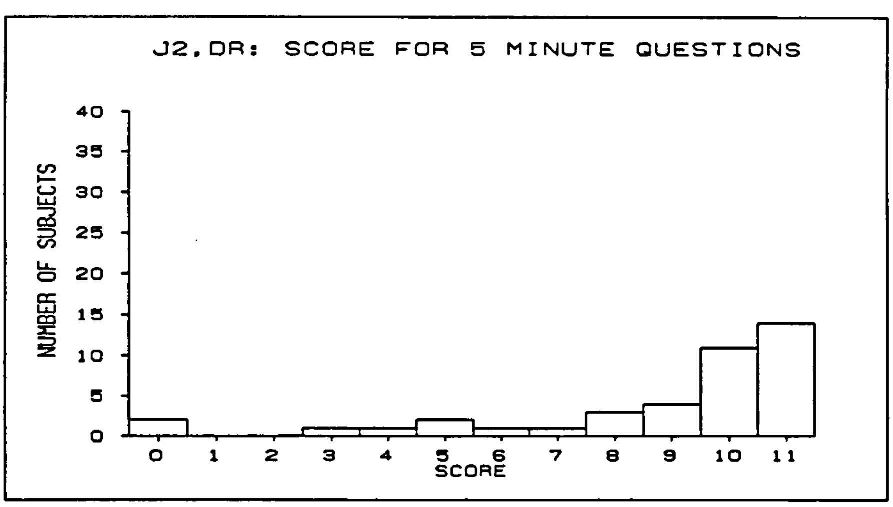
3.7


I3.DR: SCORE FOR 5 MINUTE QUESTIONS
NUMBER OF SUBJECTS
40
35
30
25
20
15
10
5
0
0 1 2 3 4 5 6 7 8 9 10 11
SCORE

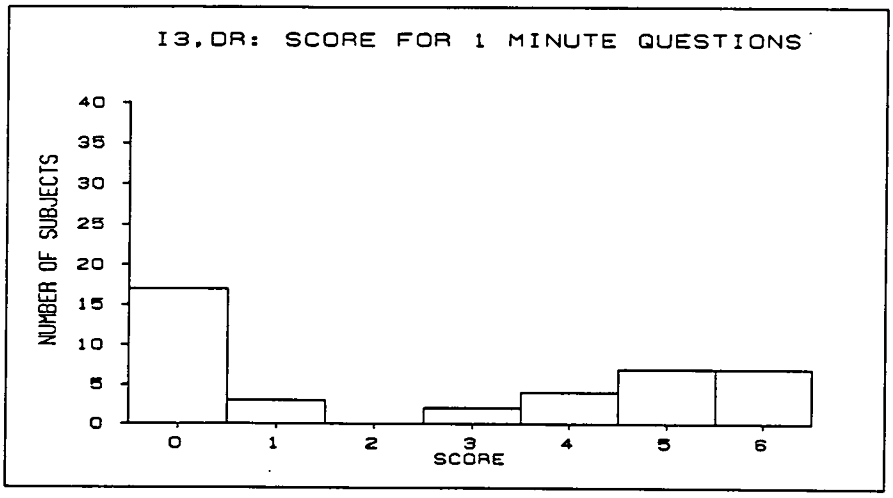
3.8


J1.DR: SCORE FOR 5 MINUTE QUESTIONS
NUMBER OF SUBJECTS
40
35
30
25
20
15
10
5
0
0 1 2 3 4 5 6 7 8 9 10 11
SCORE

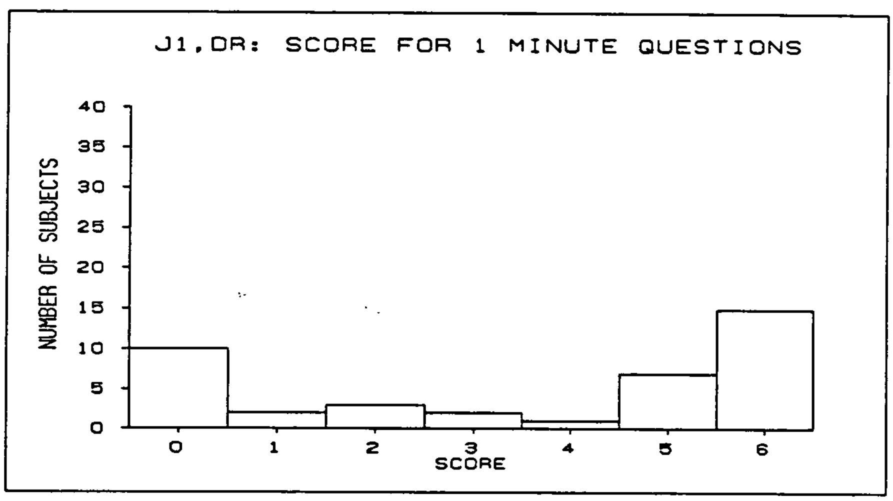
3.9


J2.DR: SCORE FOR 5 MINUTE QUESTIONS
NUMBER OF SUBJECTS
40
35
30
25
20
15
10
5
0
0 1 2 3 4 5 6 7 8 9 10 11
SCORE

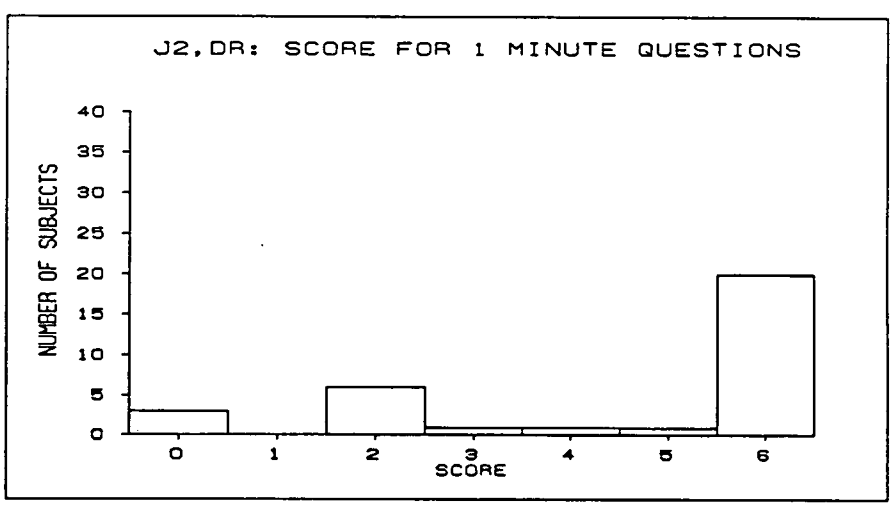
3.10


I3,DR: SCORE FOR 1 MINUTE QUESTIONS
NUMBER OF SUBJECTS
40
35
30
25
20
15
10
5
0
0
1
2
3
4
5
6
SCORE

3.11


J1,DR: SCORE FOR 1 MINUTE QUESTIONS
NUMBER OF SUBJECTS
40
35
30
25
20
15
10
5
0
0
1
2
3
4
5
6
SCORE

3.12


J2,DR: SCORE FOR 1 MINUTE QUESTIONS
NUMBER OF SUBJECTS
40
35
30
25
20
15
10
5
0
0
1
2
3
4
5
6
SCORE

3.13

over a period of time, and is certainly far from complete at the age groups considered in this study. Nevertheless there is a suggestion that some children may benefit from access to certain general principles which enables them to make a more rapid transition from inability to tell time on the five and one minute points, to mastery of these skills.

An attempt to understand more about the way in which children respond when asked to identify time on a digital clock, must necessarily turn towards an examination of the stimulus itself.

3.2.2 A Comparison Of The Various Points Of The Clock

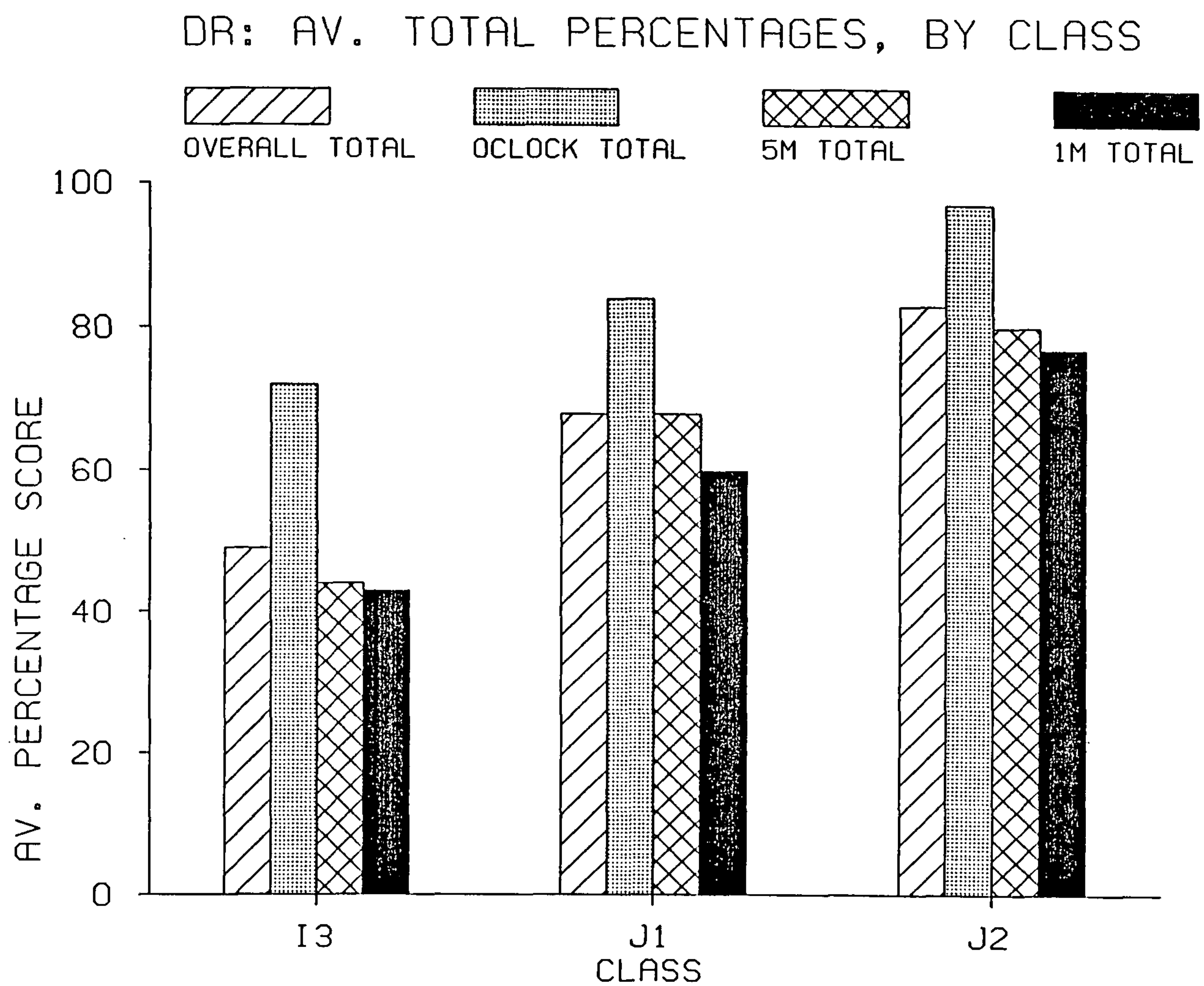
3.2.2.1 The Three Parts Of The Test

In order to see to what extent, if any, subjects' performance when reading digital time is affected by the time presented, the total percentage scores in response to questions on the o'clock, five minute, and one minute points were compared. These data are presented for each class (figure 3.14).

Subjects' clearly find times on the o'clock easier to read than those on either the five or the one minute points. The discrepancy in response to question types is a little more marked between the youngest class than in the following two years. A T test was carried out on the scores for o'clock reading and those for reading time to the five minute point. The difference between the scores was found to be significant, $T = 6.35$, $p < .001$. A T test on the difference between o'clock and one minute scores was also significant, $T = 6.96$, $p < .001$.

There is a slight tendency for children to perform better when reading times on the five minute than on the one minute point. A T test between the five and one minute scores was found to be significant, $T = 2.41$, $p < .05$, but less so than the previous comparisons.

Just as total percentages overall were seen to be subject to an age effect, increasing steadily with age for both analogue and digital reading, so this is the case for each of the three parts of the digital reading test. For o'clock questions the means were 2.9, 3.4,


DR: AV. TOTAL PERCENTAGES, BY CLASS
OVERALL TOTAL
OCLOCK TOTAL
5M TOTAL
1M TOTAL
100
80
60
40
20
0
AV. PERCENTAGE SCORE
I3
J1
J2
CLASS

3.14

and 3.9, and there was a class effect $F(2,108) = 6.97$ ($p<.001$). For the five minute questions the means were 4.8, 7.4 and 8.9 , and there was a class effect $F(2,108) = 12.27$ ($p<.001$). For the one minute questions the means were 2.55, 3.575 and 4.6, and there was a class effect, $F(2,108) = 7.55$ ($p<.001$).

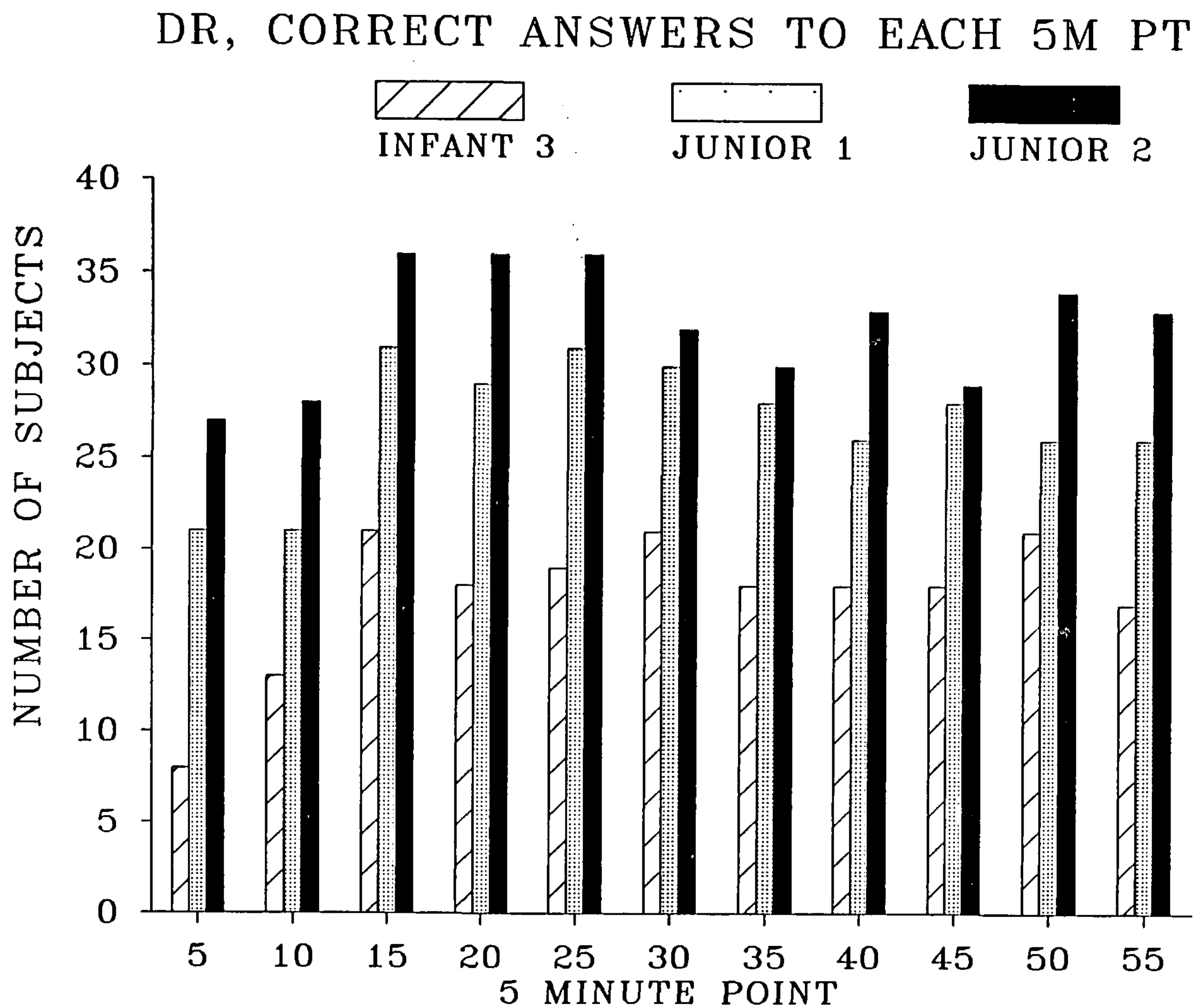
The pattern of response to different questions is reasonable when the nature of digital time is considered. The skills required to read a time on the o'clock such as 2:00 are likely to be somewhat removed from those required to read a time on the five minute point such as 2:25, or on the one minute point such as 2:26, whereas there is likely to be less difference in the skills required to read the latter two times.

3.2.2.2 The Five Minute Points Of The Clock

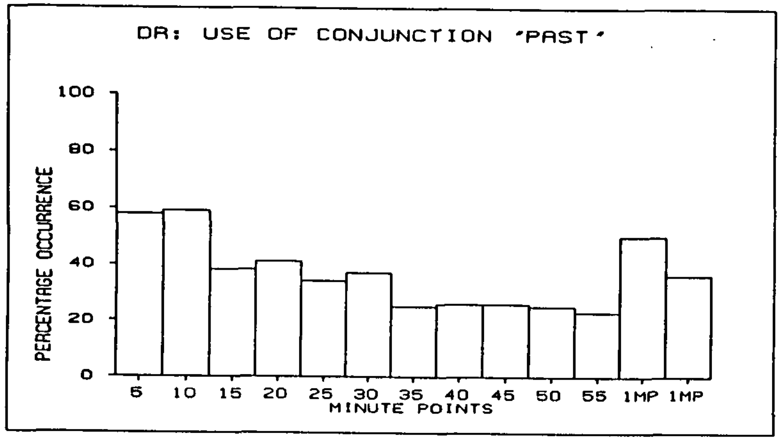
In order to see whether any particular points of the clock in addition to the o'clock point are any easier or more difficult than others, the number of subjects answering correctly the questions on each five minute point, for the three age groups was examined (figure 3.15).

In spite of the fact that ability to identify digital time correctly increases with age at each point, the overall pattern of response to the points of the clock differs little. That no particular points present special difficulty is confirmed by a non-significant Chi-squared test. However there do seem to be particularly low scores in response to questions on the 5 and 10 minute points. Low scores on the 5 minute point may be accounted for by place value confusions whereby children report the time as 50 minutes past the hour.

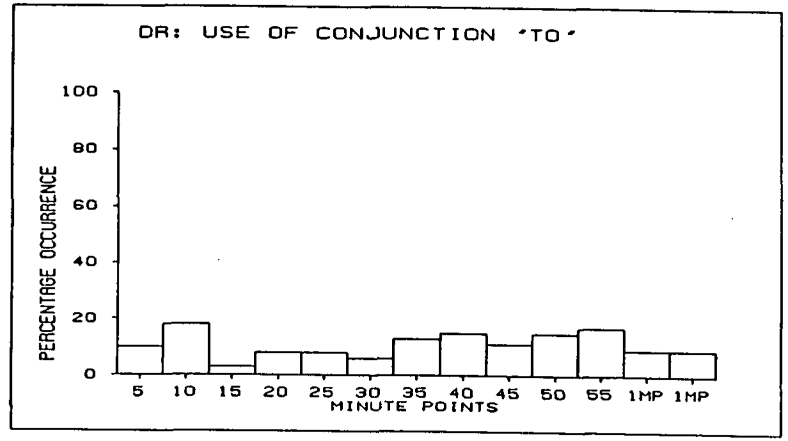
Although children do not respond differently to the five minute points of the clock, in terms of attaining a correct answer, a look at the conjunctions used to express time at each of the five minute points (figures 3.16-3.19) shows that reference to time *is* affected slightly by the stimulus presented. Since subjects were asked three one minute questions on the first half of the clock and three one minute questions on the second half of the clock, it was possible to measure conjunction use on each side of the clock for one minute questions. Percentage occurrence is shown for one minute times on the first half


DR, CORRECT ANSWERS TO EACH 5M PT
INFANT 3
JUNIOR 1
JUNIOR 2
NUMBER OF SUBJECTS
0
5
10
15
20
25
30
35
40
5
10
15
20
25
30
35
40
45
50
55
5 MINUTE POINT

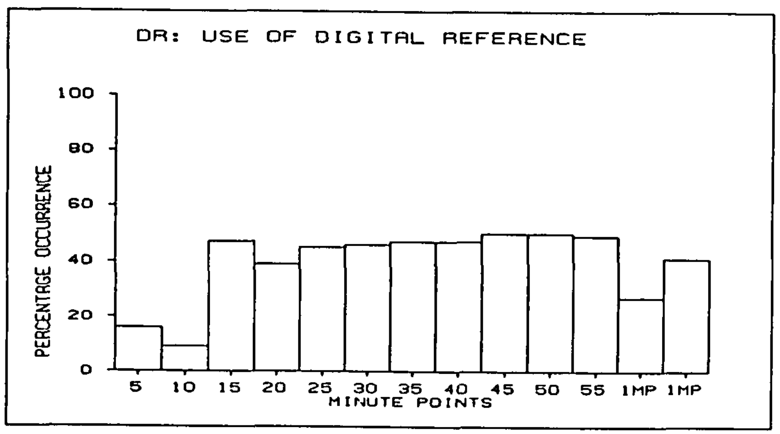
3.15



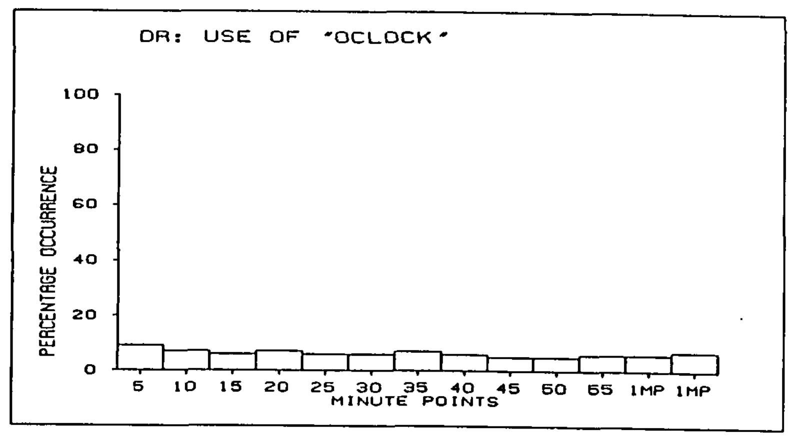
3.16



3.17



3.18



3.19

of the clock followed by those on the second.

The most frequently used form of reference is digital for all points except the five and ten minute points, and the one minute points on the first half of the clock, where "past" is the preferred term of reference. However the "past" conjunction is used almost as frequently as the digital form of reference for times up to the thirty minute point. Thus the two half hours of the clock are being distinguished by readers, both when read to the five minute and to the one minute level. In addition the 5 and 10 minute points are treated differently from the others, and this confirms what was found from looking at the percentage correct answers at each point.

3.2.2.3 Conclusion

Thus although there is some difference in the way in which children respond to the various five minute points of the clock face, the magnitude of these is too small for them to be considered significant differences. In future, it may be more reasonable to consider digital time in the light of divisions other than the traditional ones, which are likely to have a significant affect on the way in which children are able to read them. For example, times that have one zero in the hour number, one zero in the minute number, and one zero in both sides of the clock.

However, since the variety of stimulus times does not seem to account for the difficulty that the subjects experienced in reading digital time, it is necessary to clarify just which aspects of the digital representation of time it is that present difficulties for children who attempt to decode it.

3.2.3 The Problematic Features Of The Digital Display Of Time

3.2.3.1 Introduction

At first sight the digital display of time may seem a reasonably straightforward way in which to convey information about time. However the poor performance levels of the subjects in this study when asked to read digital time has shown the task to be more complicated than this.

In fact, if the digital representation of time is analysed, it can be seen that there are a number of inherent factors that are potentially confusing. In order to read digital time satisfactorily, a child must... 1) recognise that the four digits communicate a time, and that this consists of an hour and a minute component, separated by a colon, 2) correctly assign the numbers on the left side of the clock to the hour component and the numbers on the right side of the clock to the minute component, 3) appropriately apply the various ways of expressing time, and 4) correctly read the digits.

Appendix VII shows the whole range of errors observed in response to reading digital time. The major misunderstandings in response to five minute questions, which were highlighted by the coding system, are presented on figure 3.20. An overview of the causes of confusions and their resulting errors are discussed below.

3.2.3.2 Forming An Hours-And-Minutes Relationship

When children are faced with a digital time to identify, they must first recognise that the problem is about properly forming an hours-and-minutes relationship. Very few children failed to view the problem in this light, those who did, however, tended to display this misunderstanding throughout the test, thereby indicating that they had not yet realised the nature of the task. The most primitive responses consisted simply of reading the digits presented, eg. 06:32 would be identified as "0,6,3,2". In some cases the digits were not read correctly, since digits might be omitted or reversed. Other responses in this category include the identification of numbers without reference to minutes and hours, eg. "60 and 32", or more rarely the use of hours or minutes twice to exclusion of the other, for example, "60 hours and 30 hours" or "60 minutes and 30 minutes".

3.20 The Main Types of Reversal Misunderstandings in Response to Reading Digital Time on the Five Minute Points

	ALL SUBJECTS	J 3	J 1	J 2
Reversal of the two hour digits, or reversal of the two minute digits, or both	17	18	12	21
Reversal of the two hour digits	9	10	7	9
Reversal of the two minute digits	9	10	6	12
Reversal of the two hour digits and of the two minute digits	1	1	1	0
Reversal of the two hour digits when a zero is not involved	0	0	0	0
Reversal of the two hour digits when a zero is involved	9	9	7	9
Reversal of the two hour digits where a zero is the first digit	8	9	7	9
Reversal of the two hour digits where a zero is the second digit	0	0	0	0
Reversal of the two minute digits when a zero is not involved	1	0	0	1
Reversal of the two minute digits when a zero is involved	8	9	5	10
Reversal of the two minute digits where a zero is the first digit	3	4	3	2
Reversal of the two minute digit where a zero is the second digit	5	5	3	9

3.2.3.3 Assignment Of Hour And Minute Labels

3.2.3.3.1 Reversal Of Hour And Minute Labels

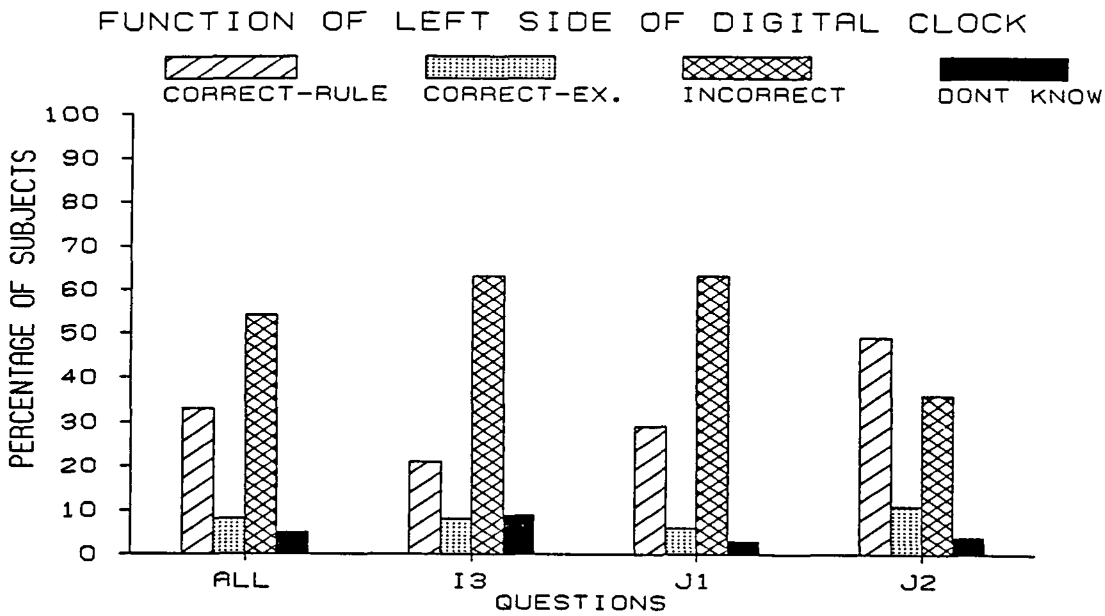
For those children who have acquired the understanding that digital time represents a value of hours and a value of minutes, it is still by no means a simple task to correctly assign these labels to the numbers. There is a potential confusion to assign the hour number to the minutes and the minute number to the hours. Indeed such a reversal seemed to be commonly displayed by children, particularly those who used the "X minutes past Y" format to express time, as they supposed digital time to be displayed in a compatible manner, thus the first number was presumed to be the minutes and the second to be the hours.

3.2.3.3.2 Reversal Of Hour And Minute Functions

How far this error is the expression of ignorance of the functions of the two sides of the digital clock, and how far it is simply the result of the impulsive application of an "X minutes past Y" format, was tested on two counts. Firstly of the reversals made, it seemed that many were answered in an "X minutes past Y" format, so this did seem to be a relevant function in the occurrence of such reversals.

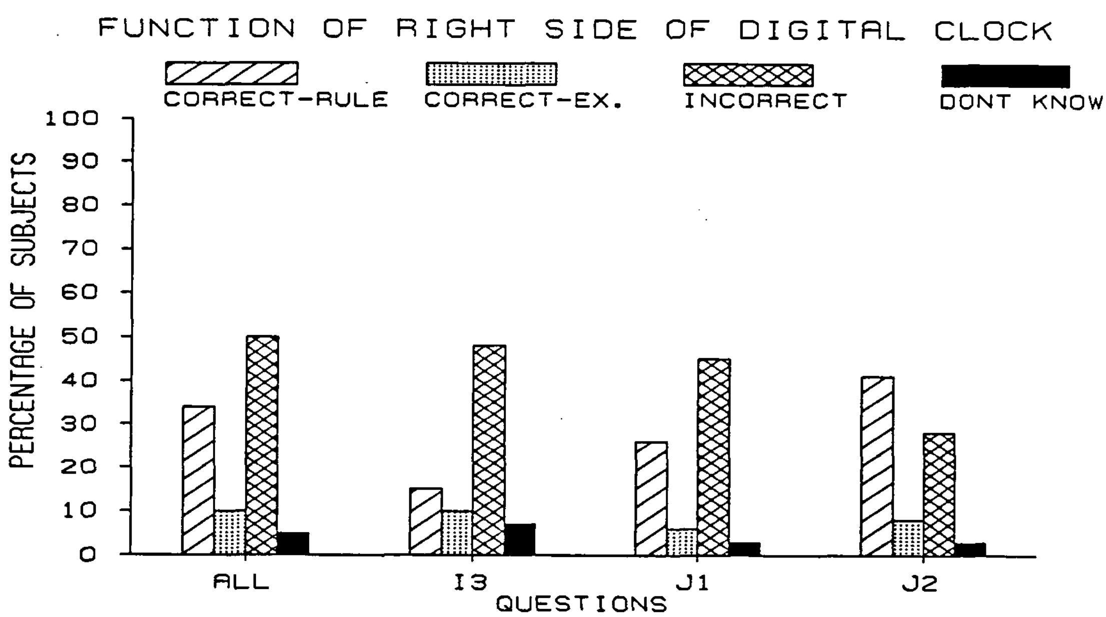
Secondly children were asked the functions of the left and right sides of the digital clock during testing. Answers were coded into four categories - a correct answer in the form of a rule, a correct answer by giving an example, an incorrect answer, and failure to give an answer. A rule would simply be reference to minutes or hours, though not necessarily by these terms, whereas an example would tend to involve an explanation of the positions of each hand in the analogue form, or the position of certain numbers in the digital clock, and a conclusion of function from these.

Figures 3.21 and 3.22 show responses to these questions, overall, and for each year group. The large number of incorrect answers makes it obvious that children are largely unaware of how minutes and hours are conveyed by the two sides of the digital clock, or at least are unable to articulate this knowledge.



FUNCTION OF LEFT SIDE OF DIGITAL CLOCK
CORRECT-RULE
CORRECT-EX.
INCORRECT
DONT KNOW
PERCENTAGE OF SUBJECTS
100
90
80
70
60
50
40
30
20
10
0
ALL
I3
J1
J2
QUESTIONS

3.21



FUNCTION OF RIGHT SIDE OF DIGITAL CLOCK
CORRECT-RULE
CORRECT-EX.
INCORRECT
DONT KNOW
PERCENTAGE OF SUBJECTS
100
90
80
70
60
50
40
30
20
10
0
ALL
I3
J1
J2
QUESTIONS

3.22

Only a very small percentage of "don't know" answers were recorded (5%), most answers were either incorrect (52%), or were correct with the articulation of a relevant rule (34%). Surprisingly few answers which were correct, but in the form of an example rather than a formal rule (9%), were recieved. It had been thought that children might pass through a stage between giving an incorrect answer and a correct one in the form of a rule, of being able to give a correct example, but this does not seem to be the case.

The trend with increase in age, as is to be expected, was a reduction in incorrect responses and an increase in the number of children who are able to articulate a correct rule. "Don't know" answers occur slightly more often in the youngest class, compared to the other two, but in all classes, the incidence of this response is very low. This is not a gradual change through the three classes, but is more marked beween the first and second year junior classes than between infant three and junior one, which suggests that most development in these understandings is taking place between the first and second year of junior school. In the first two years about 70% of subjects are responding unsatisfactorily, whereas this is reduced to under 50% by the last class shown.

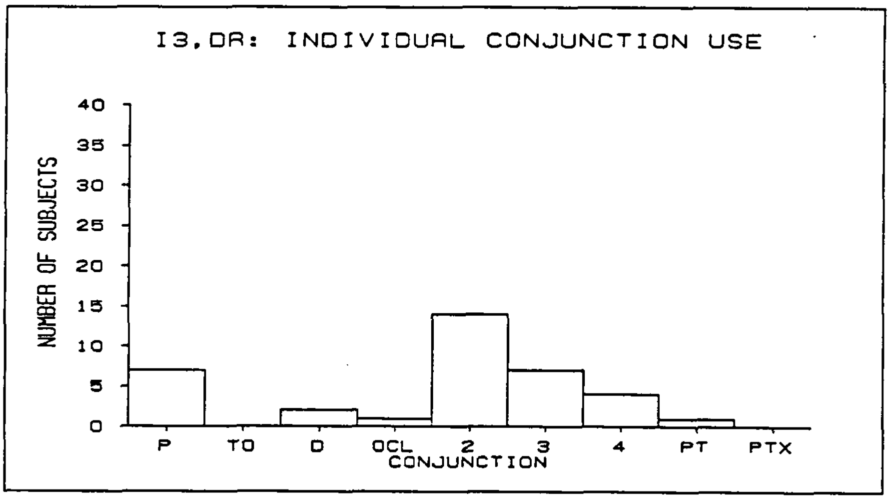
3.2.3.3.3 Relationship Between Reversal Of Labels And Of Functions

In future, it would be interesting to investigate those children who reversed the functions of the two sides of the clock, to see whether this misunderstanding was reflected in their test performance.

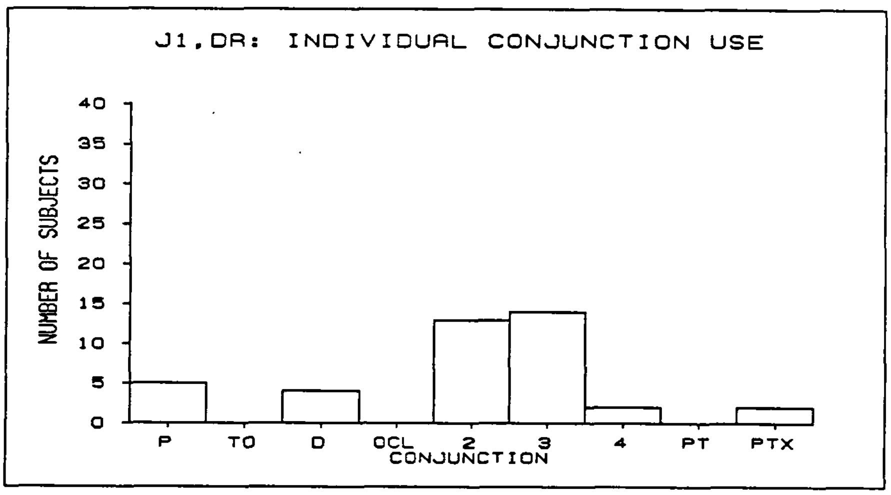
3.2.3.4 Variations Used To Express Time

3.2.3.4.1 Confusion About Use Of Time Variations

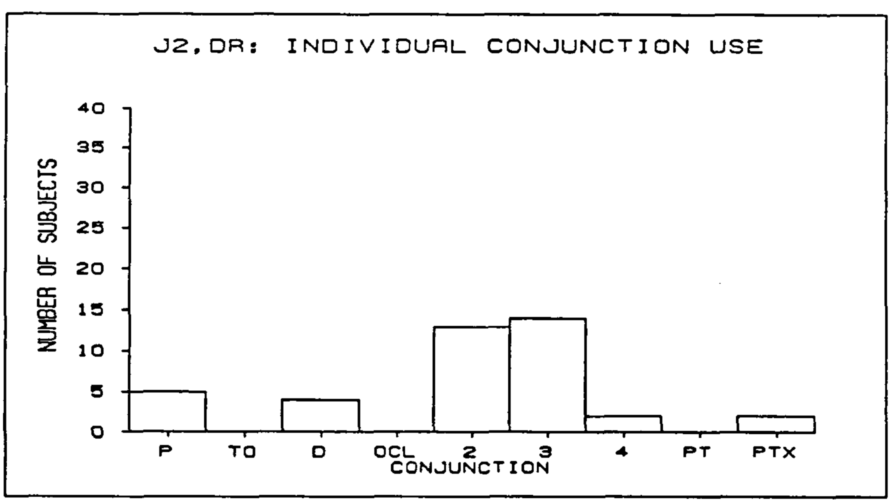
The majority of children reading digital time responded in a digital or "minutes past" format. Figures 3.23-3.25 show the number of children who responded predominantly (ie. in at least 80% of cases), with "past", "to", digital, or "o'clock" expression. It also shows the number of children who used a mixture of two, three, or four of these options. A combination of "past" and "to" is treated separately, and


I3, DR: INDIVIDUAL CONJUNCTION USE
NUMBER OF SUBJECTS
40
35
30
25
20
15
10
5
0
P
TO
D
OCL
2
3
4
PT
PTX
CONJUNCTION

3.23


J1, DR: INDIVIDUAL CONJUNCTION USE
NUMBER OF SUBJECTS
40
35
30
25
20
15
10
5
0
P
TO
D
OCL
2
3
4
PT
PTX
CONJUNCTION

3.24


J2, DR: INDIVIDUAL CONJUNCTION USE
NUMBER OF SUBJECTS
40
35
30
25
20
15
10
5
0
P
TO
D
OCL
2
3
4
PT
PTX
CONJUNCTION

3.25

the number of children who used this method correctly, that is, applied "past" to times on the first half of the clock, and "to" on the second half of the clock, is shown separately from the number of children who made incorrect attempts.

Subjects are clearly using a large number of variations to express time without the application of a logical strategy. This suggests they are confused by the choice they are faced with and see no reason to apply one method, any more than the other.

3.2.3.4.2 Inappropriate Use Of Time Variations

Children bring with them to the digital reading task, understandings of time learned on the analogue clock, so that they will try to apply fractional, "minutes past" and "minutes to" expressions of time to the digital display, as well as the use of the digital reference. However, since additional time variations can only be applied to digital time when adapted to fit the changed circumstances from analogue time, children who fail to make these adaptations will clearly experience difficulties.

Digital time is presented as minutes past the hour, and so is most easily read either digitally or as minutes past the hour. A common mistake was to correctly read both the minutes and the hours, but to join them with the conjunction "to", so if the target time was 08:40, the response would be "40 minutes to 8".

Some children tried to apply the "X minutes past Y" format directly to digital time, and so effectively reversed the hour and minute components, for example 06:35 would be read as "6 minutes past 35". Others tried to apply the "X minutes to Y" format to digital time, and in immature time readers this was simply applied directly to the numbers presented. However some particularly advanced children who had more or less mastered telling digital time in an "X past Y" format, and recognised that time is referred to as "to the hour" after the 30 minute point has been passed, selectively applied the "to" conjunction to those times after 30 minutes past the hour. However since not only the minutes but also the hours, must be transformed in such cases, the process was especially vulnerable to mistakes. An example would be

08:40, where the transformation required would result in the response "20 to 9".

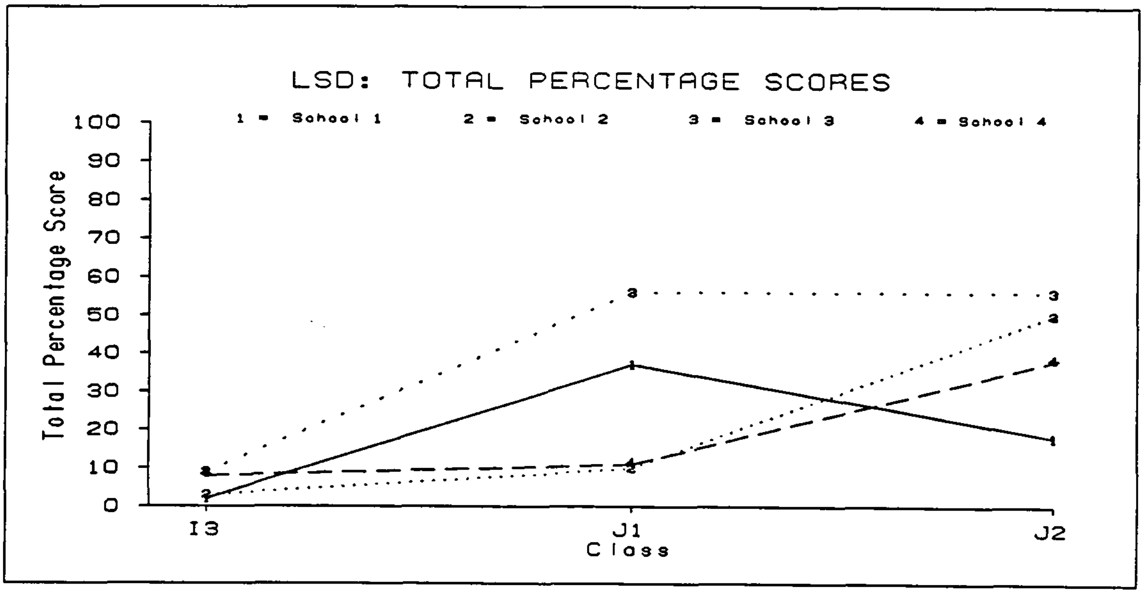
3.2.3.5 Reading Digits

The enormous number of mistakes made in actually reading the digits clearly indicated that this was not as simple a cognitive activity as it might seem. The most common errors seemed to be those involving misreading of numerals by reversing the two hour digits, or the two minute digits. This is not surprising since it is known that children have considerable tendency to reverse left and right orientation, order of writing numbers and letters, and even the numbers and letters themselves. Springer (1951) found several examples of this trait. Some of her subjects were found to label their clocks anticlockwise and to write the numbers in a reversed manner.

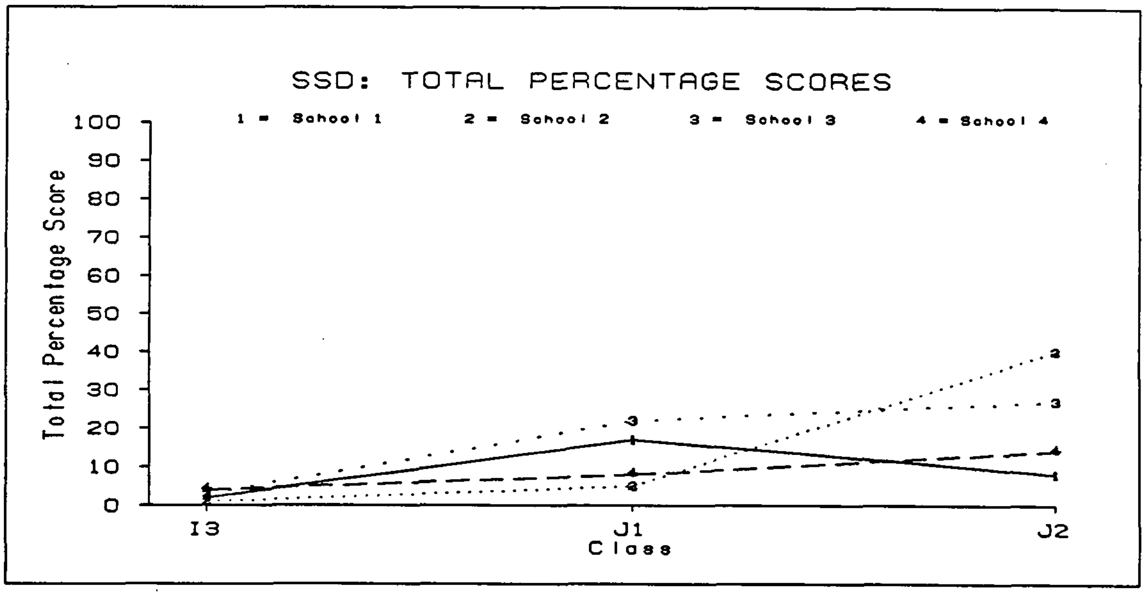
Errors involving reversing two digits appeared to be much more common when one digit was a zero. If this is so, it would indicate that knowledge about place value in children of the ages observed is clearly far from developed.

The gravity and extent of place value confusions is evident from a comparison between setting digital time marked according to lax criteria, in which allowances were made for place value confusions, and setting digital time marked according to strict criteria for which no such allowances were made. Figures 3.26 and 3.27 show this data. The marked reduction in percentage scores with the application of strict criteria to the data, shows the evident prevalence of place value confusions which were not apparent from the reading data alone.

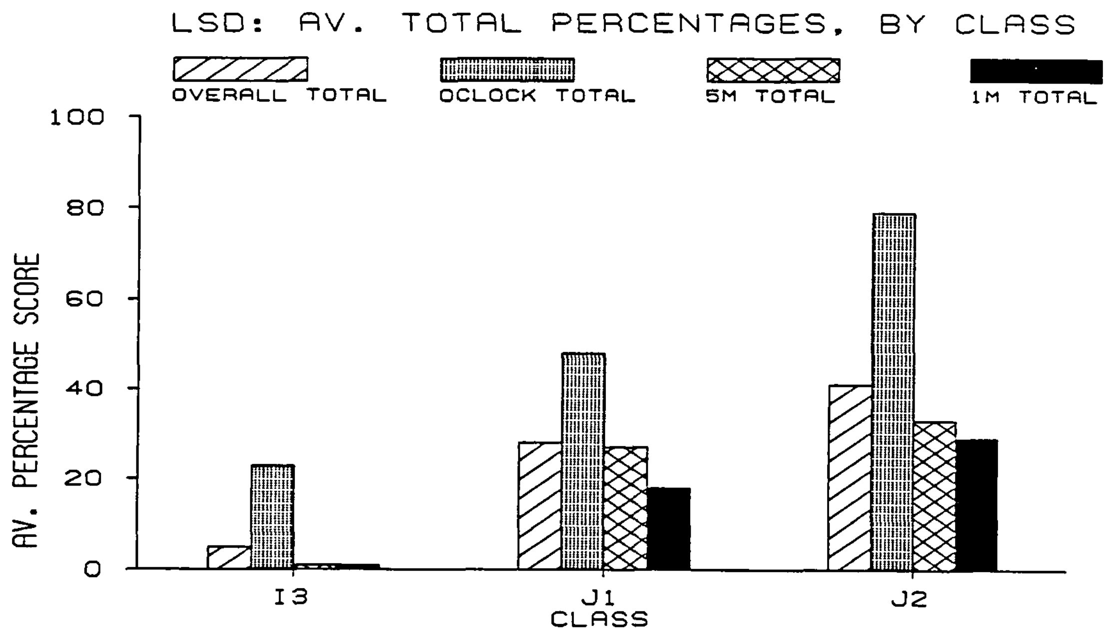
A comparison between lax and strict setting scores on o'clock, five minute and one minute questions (figures 3.28 and 3.29) indicates that the reducing effect of strict criteria on the scores occurs across all types of question, but is more prevalent on the o'clock questions. That place value is more of a problem on the o'clock times, is not surprising since in three quarters of these cases, there are three zeros in the time.



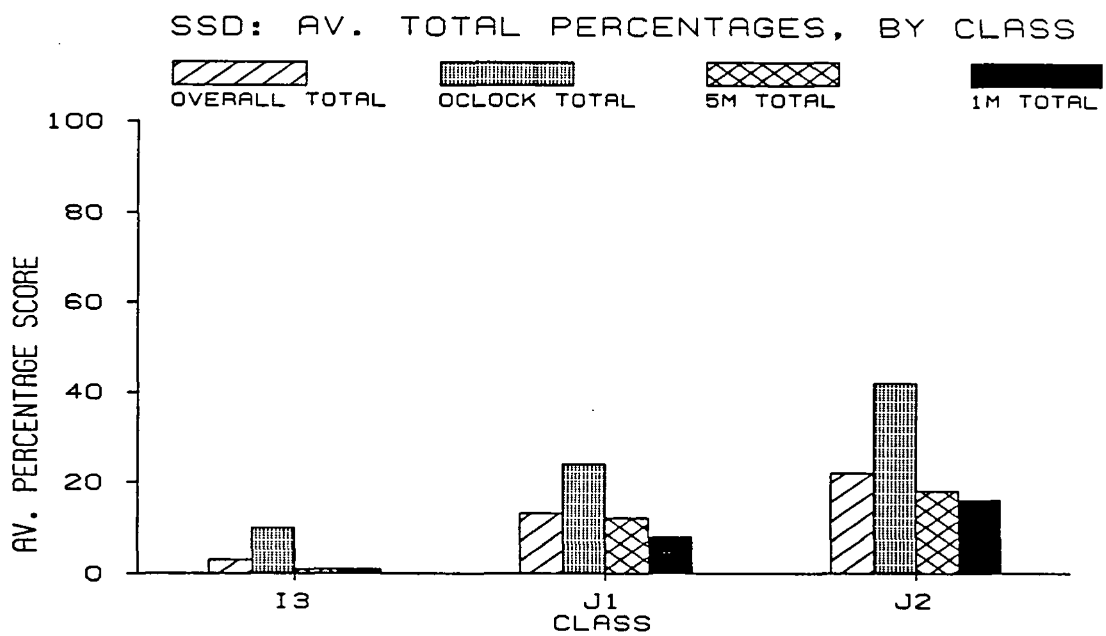
3.26 Graph of Total Percentage Scores for setting Digital Time (Marked According to Lax Criteria)



3.27 Graph of Total Percentage Scores for setting Digital Time (Marked According to Strict Criteria)



3.28 Average Total Percentages, by Class, for Setting Digital Time (Marked According to Lax Criteria)



3.29 Average Total Percentages, by Class, for Setting Digital Time (Marked According to Strict Criteria)

3.2.4 Conclusion

The examination of the nature of the stimulus of digital time has revealed the aspects of it which present children with difficulties when attempting to decode the information it contains. A comparison between children's abilities to identify digital time and reproduce it has seriously called into question the implications of their scores on simply reading time. Data on children's ability to set time has shown that the understandings which they appear to exhibit when reading time are in fact not as advanced as they appear, and there are some serious deficits in children's knowledge.

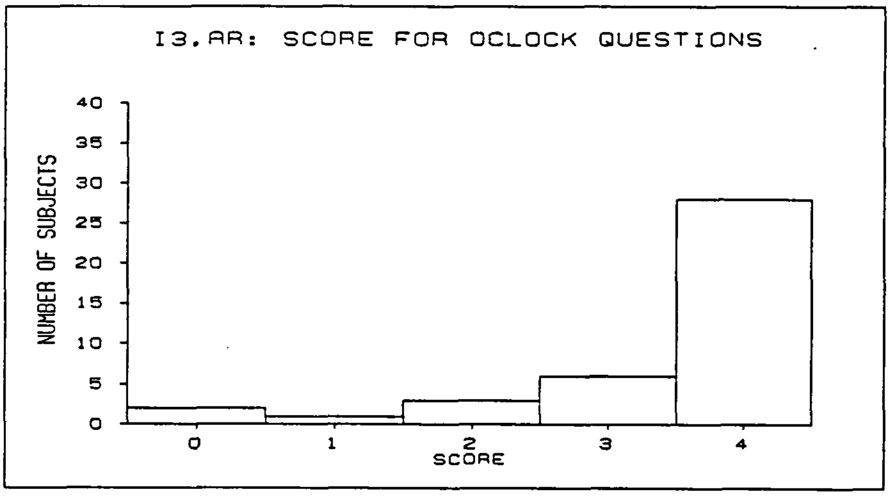
A similarly thorough investigation of the nature of analogue time was undertaken to see what factors of this representation of time could account for children's poor level of performance on the test. Firstly, in order to illuminate the way in which children acquire time telling skills, the nature of the development itself was considered.

3.3 DIFFICULTIES IN PROCESSING THE ANALOGUE REPRESENTATION OF TIME

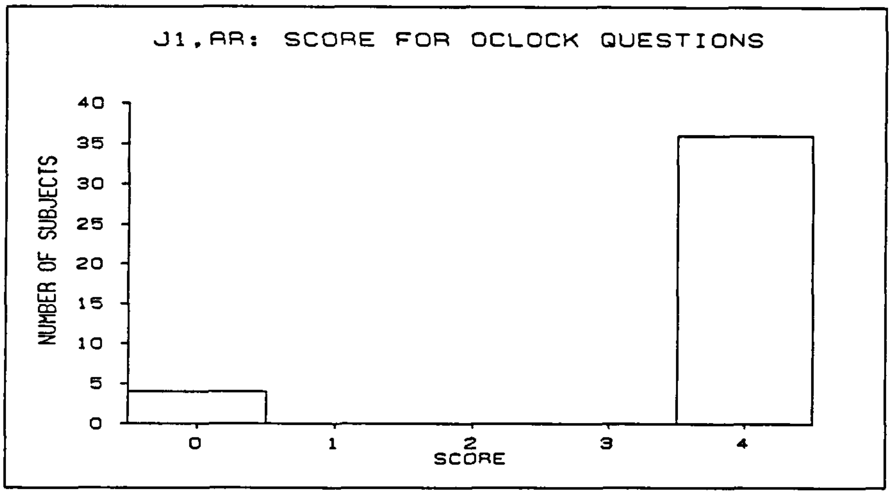
3.3.1 The Nature Of The Acquisition Of Analogue Time Telling Skills

To determine whether the acquisition of the ability to tell analogue time is more a gradual or a sudden process, the frequency distributions of subjects' scores were examined. The idea of sudden access to the skill predicts a bimodal frequency distribution of scores, with some subjects scoring low and others scoring high, but few subjects falling between these these two categories. On the other hand, a gradual acquisition of the skill would predict that scores would be relatively evenly distributed over the possible spectrum.

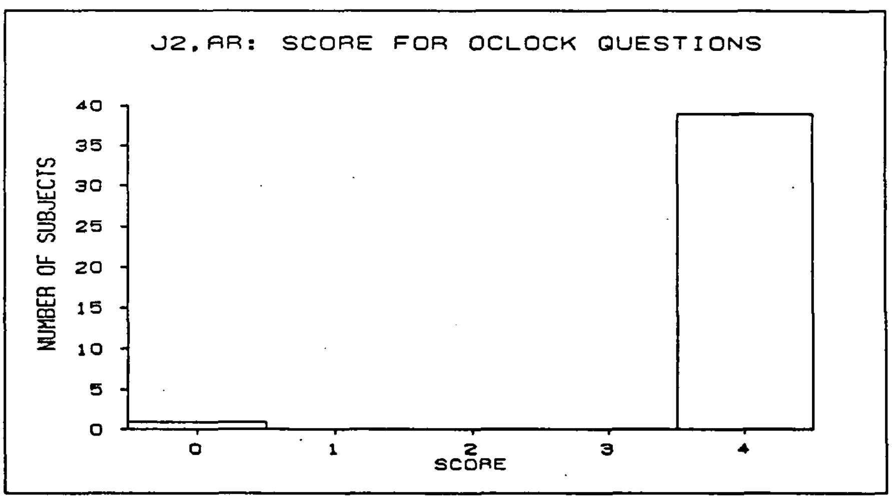
There is little to be gained from looking at the distribution of scores in response to the o'clock questions since the children tested had largely mastered the identification of such times. Figures 3.30-3.32 show the number of subjects attaining each possible score from nought to four, in response to questions on the o'clock point. There are signs of bimodality, but in the infants, who are least advanced, there are pupils at each possible score level.


I3.AR: SCORE FOR OCLOCK QUESTIONS
NUMBER OF SUBJECTS
40
35
30
25
20
15
10
5
0
0
1
2
3
4
SCORE

3.30


J1.AR: SCORE FOR OCLOCK QUESTIONS
NUMBER OF SUBJECTS
40
35
30
25
20
15
10
5
0
0
1
2
3
4
SCORE

3.31


J2.AR: SCORE FOR OCLOCK QUESTIONS
NUMBER OF SUBJECTS
40
35
30
25
20
15
10
5
0
0
1
2
3
4
SCORE

3.32

However the nature of the acquisition of the skills of reading analogue time to the five and one minute points can be usefully considered. The distribution of scores in response to reading analogue time to the five minute point are displayed, by class on figures 3.33-3.35. A high number of subjects score 0 or 1 out of the eleven five minute point questions asked, but are distributed fairly evenly over subsequent scores, dispelling any thoughts that understanding of time at 5 minute points 'clicks' so that subjects suddenly go from being unable to perform the skill, to being quite competent at it, as some teachers suggested during discussions.

Figures 3.36-3.38 show the number of subjects who scored each possible score from nought to six on the one minute questions. A similarly well distributed pattern of scores is observed for both the junior classes, although a large number of subjects of both these classes score zero and all but one of the infant children score zero. This situation occurs because the development of ability to tell analogue time to the one minute point lags behind that to tell time to the five minute point, and many children have simply not yet understood sufficiently to get even one question correct.

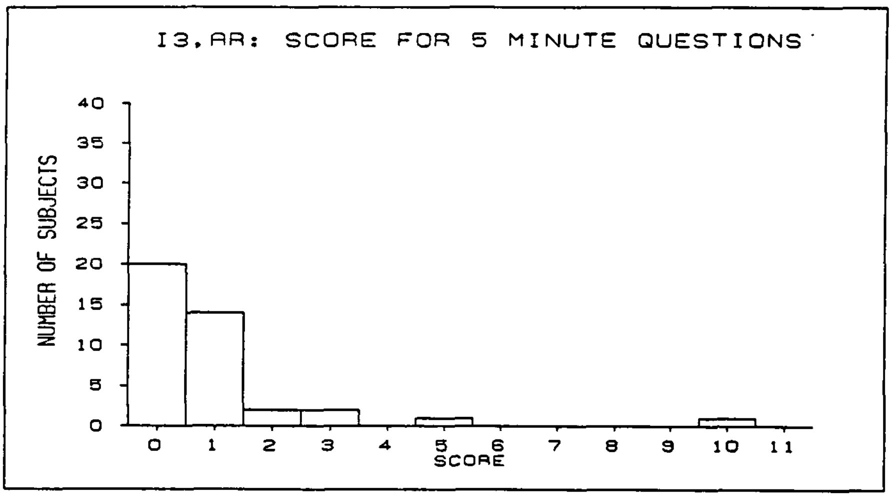
The frequency distributions of scores at the five and one minute points of the analogue clock therefore clearly indicate that acquisition of ability to tell time on these points must be a gradual process. However, if the performance of children at a more advanced level of time telling was examined, it may be that there would be some bimodality of the distribution of score values, indicating that some children do benefit from access to general principles.

Having determined the nature of the development of the ability to identify analogue time, it is necessary to examine the effects of the various points as stimuli to the time reader.

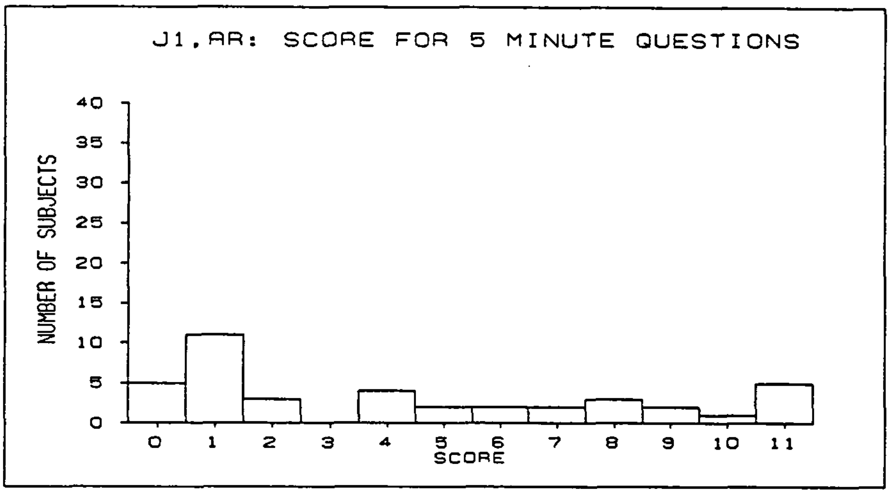
3.3.2 A Comparison Of The Various Points Of The Clock

3.3.2.1 The Three Parts Of The Test

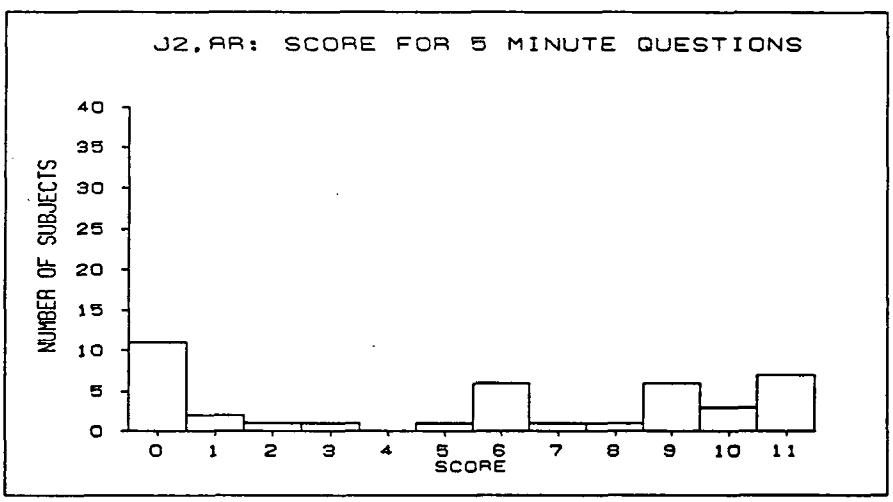
To understand why children are performing poorly, the three parts of


I3.AR: SCORE FOR 5 MINUTE QUESTIONS
NUMBER OF SUBJECTS
40
35
30
25
20
15
10
5
0
0 1 2 3 4 5 6 7 8 9 10 11
SCORE

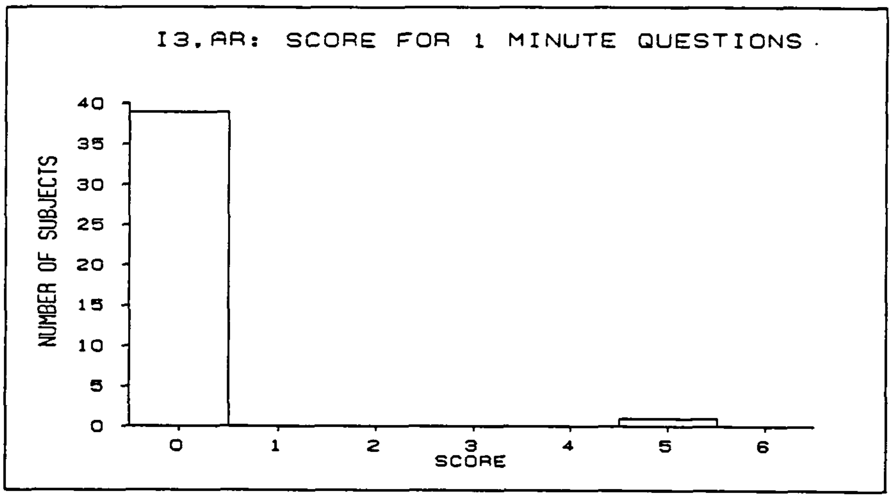
3.33


J1.AR: SCORE FOR 5 MINUTE QUESTIONS
NUMBER OF SUBJECTS
40
35
30
25
20
15
10
5
0
0 1 2 3 4 5 6 7 8 9 10 11
SCORE

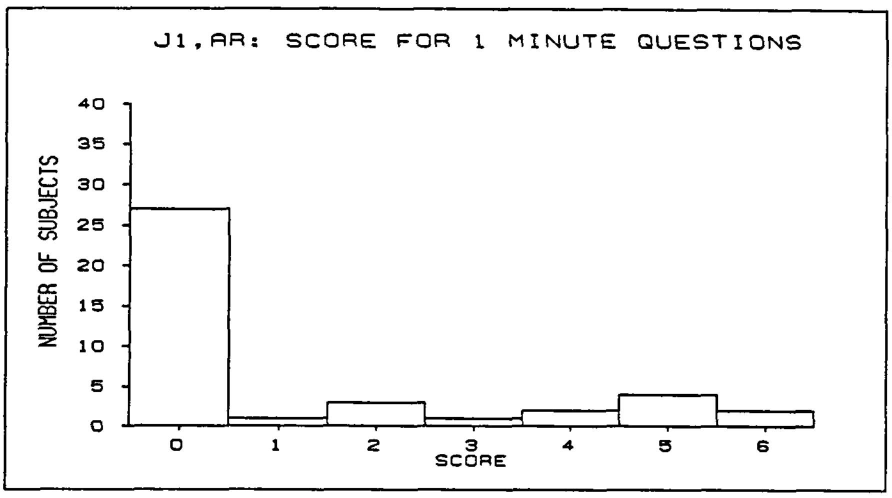
3.34


J2.AR: SCORE FOR 5 MINUTE QUESTIONS
NUMBER OF SUBJECTS
40
35
30
25
20
15
10
5
0
0 1 2 3 4 5 6 7 8 9 10 11
SCORE

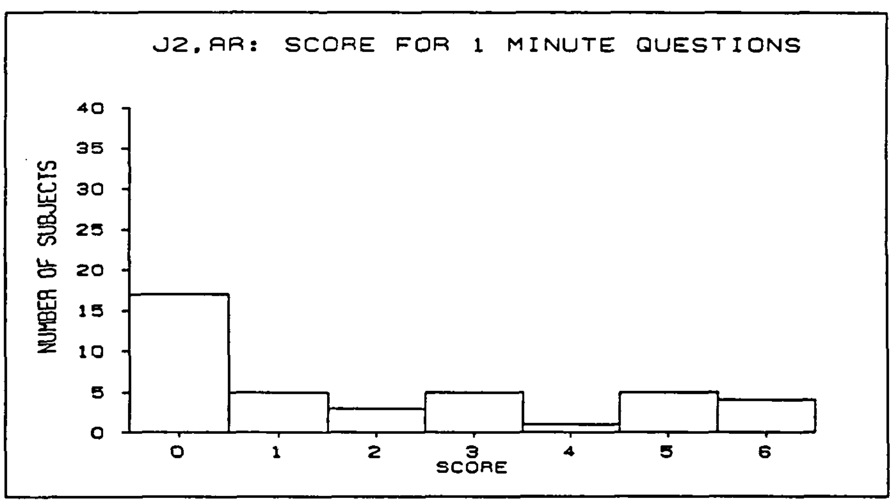
3.35


I3, AR: SCORE FOR 1 MINUTE QUESTIONS
NUMBER OF SUBJECTS
40
35
30
25
20
15
10
5
0
0
1
2
3
4
5
6
SCORE

3.36


J1, AR: SCORE FOR 1 MINUTE QUESTIONS
NUMBER OF SUBJECTS
40
35
30
25
20
15
10
5
0
0
1
2
3
4
5
6
SCORE

3.37


J2, AR: SCORE FOR 1 MINUTE QUESTIONS
NUMBER OF SUBJECTS
40
35
30
25
20
15
10
5
0
0
1
2
3
4
5
6
SCORE

3.38

the test - o'clock, five minute, and one minute questions, were looked at to see if this situation occurs evenly across them, or is concentrated into certain parts of the time telling task. Average total percentages were computed for the three parts of the test (figure 3.39).

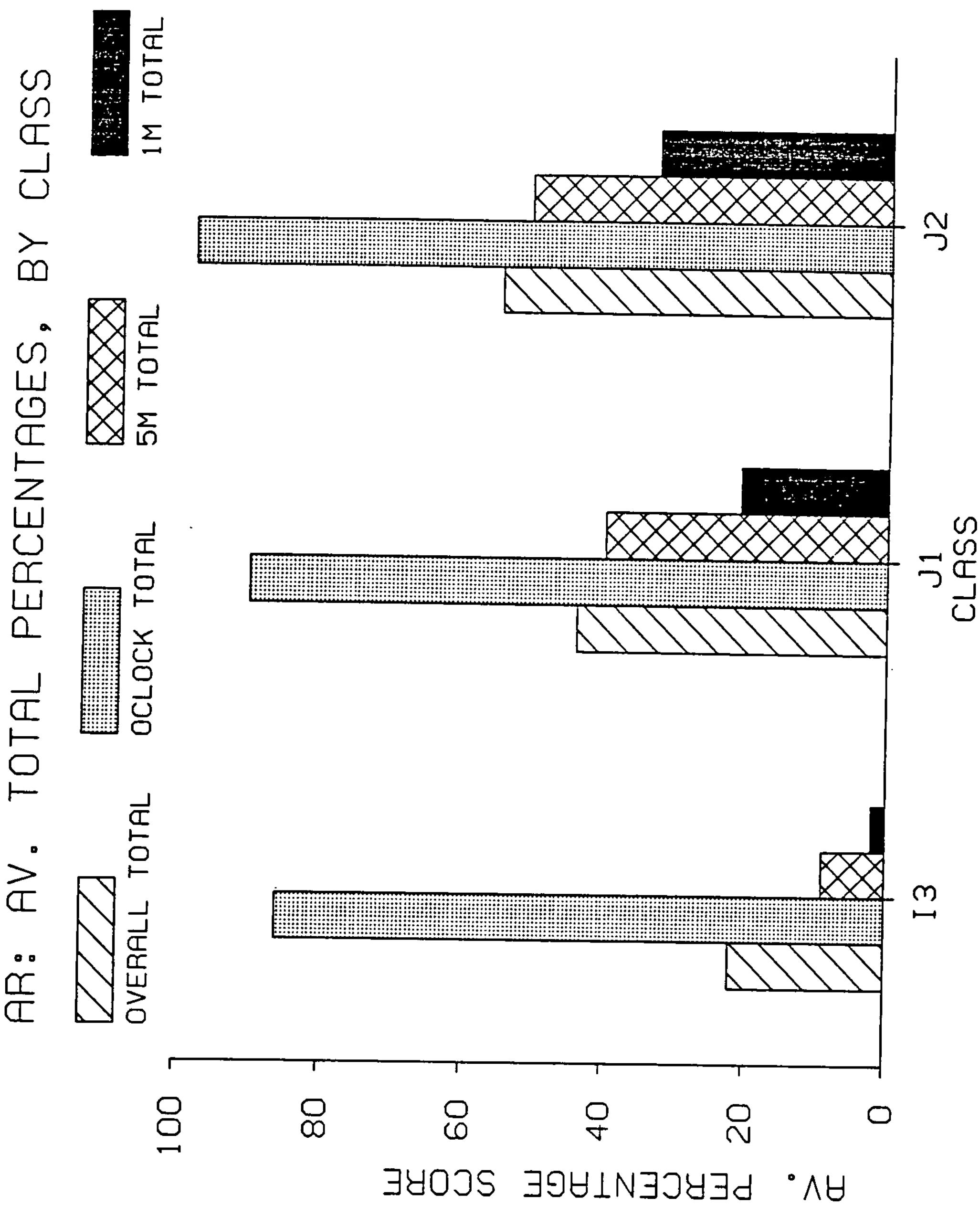
The most striking feature of the data is the enormous difference in average percentage score attained on questions concerning the o'clock points and on those on the minute points. Subjects clearly found the o'clock questions much easier than others, with children at all three ages scoring over 80% correct on these questions. There is also a markedly greater average percentage score in response to five minute questions than those on the one minute point. In every class for analogue reading, the o'clock score is greater than the five minute score which in turn is greater than the one minute score.

A T test was carried out on the scores for o'clock reading and those for reading time to the five minute point. The difference between the scores was found to be significant, $T = 15.88$, $p < .001$. A T test on the difference between o'clock and one minute scores was also significant, $T = 19.94$, $p < .001$, as was a T test on the difference between five and one minute scores, $T = 6.37$, $p < .001$.

Such an outcome seems reasonable when the nature of analogue time is considered. It is not surprising that the skills required to read two times such as 12:00 and 12:25, or 2:25 and 2:26 are somewhat removed.

Clearly children found the order of difficulty of questions as one would expect, but how far this is a function of developmental sequence, and how far it is concerned with the order in which they are taught these aspects of time telling is unknown. Third year infant pupils, for example, are usually not taught to tell time to the minute, and many also do not cover time on the five minute point, so this probably accounts largely for their poor scores on these parts of the test.

As with the overall percentage scores, there are age effects. For o'clock questions the means were 3.43, 3.6 and 3.9, but there were no



AR: AV. TOTAL PERCENTAGES, BY CLASS
OVERALL TOTAL
OCLOCK TOTAL
5M TOTAL
1M TOTAL
AV. PERCENTAGE SCORE
0
20
40
60
80
100
I3
J1
J2
CLASS

3.39

significant effects. For five minute questions there is a significant age effect $F(2,108) = 6.97$ ($p<.001$), the means for the three classes from infants to second year juniors are 1.0, 4.4 and 5.6 respectively. A School effect $F(3,108) = 2.75$ ($p<.05$) and an interactional effect $F(6,108) = 2.64$ ($p<.05$) were also found. For one minute questions there was a significant class effect $F(2,108) = 12.21$ ($p<.001$), and a school effect, $F(3,108) = 4.75$ ($p<.05$). Means were 0.1, 1.3, and 2.0.

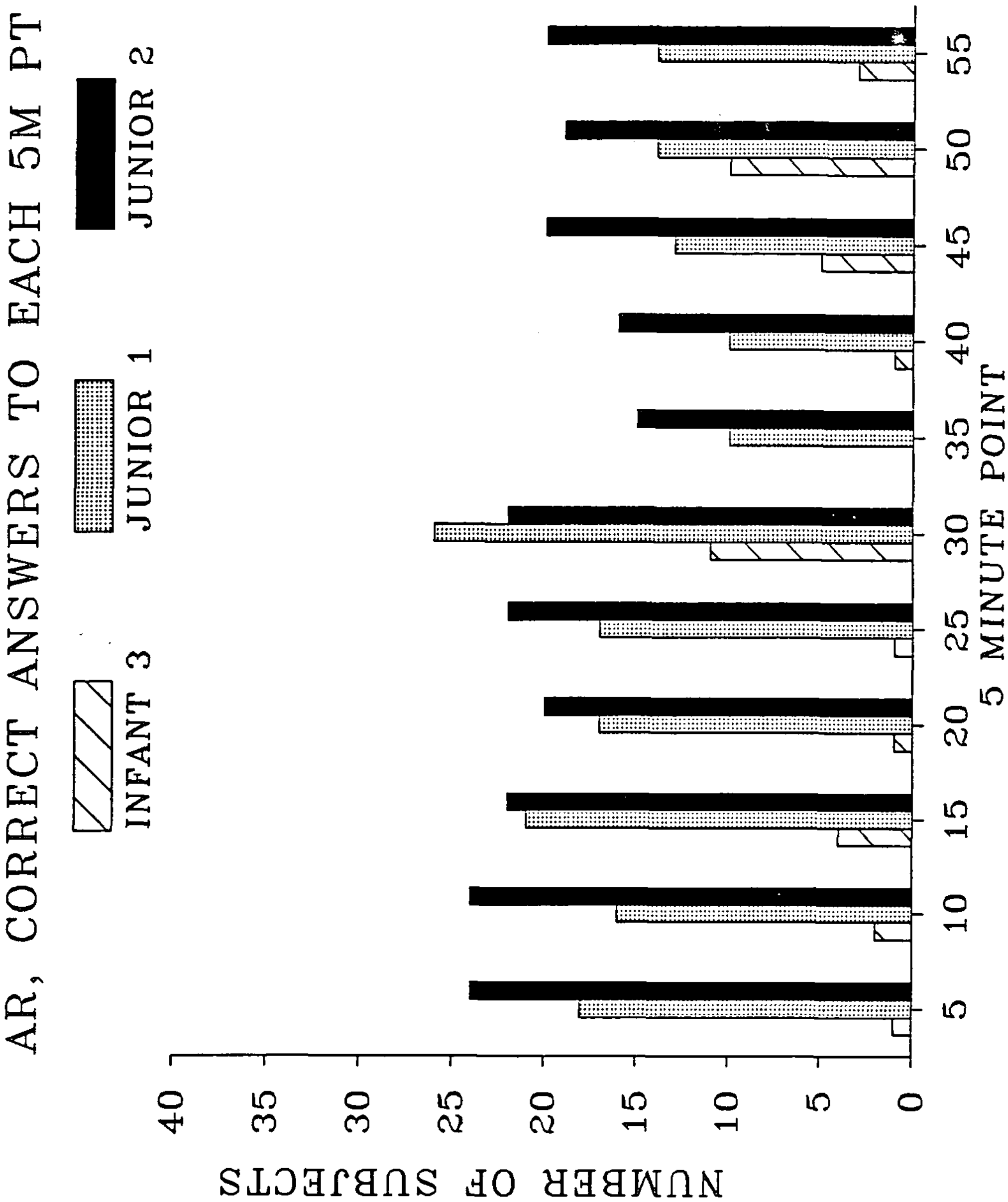
3.3.2.2 The Five Minute Points

In order to see whether any particular points of the clock in addition to the o'clock point are any easier or more difficult than others, children's score at each five minute point was examined (Figure 3.40).

The number of subjects responding correctly to each five minute point is similar, in fact a Chi-squared test is not significant. However the 30 minute point is clearly more salient than other points to children of the two youngest classes and this is not surprising considering the emphasis placed on "half past" in teaching as well as the seemingly clearly recognisable and memorable position of the hand when pointing directly downwards at the six. Contrary to what might have been expected considering the common fractional teaching approach to time, there is only very slight advantage to the 15 and 45 minute points at the infant level, and this disappears in the latter case by J1, and in the former case by J2.

The reason for a large number of correct responses to times on the 50 minute point is that the hour number at this point of the clock is "10" which corresponds to the number of minutes to the hour. Thus children who use only the hour metric and report the time as "10 to the hour", get the question correct by chance rather than design. This effect declines by the junior years with the reduction in tendency to use the hour metric only. Two other points, the 35 and 40 minute points, do incur a lower number of correct responses than the other points of the clock, although the effect is not large. The reason for their difficulty may be that they are the last to be learned in the past/to method.

To investigate further the effect of stimulus point, the conjunctions


AR, CORRECT ANSWERS TO EACH 5M PT
INFANT 3
JUNIOR 1
JUNIOR 2
NUMBER OF SUBJECTS
0
5
10
15
20
25
30
35
40
5
10
15
20
25
30
35
40
45
50
55
5 MINUTE POINT

3.40

used to read analogue time on each five minute point were examined. Figures 3.41-3.44 show this data for each class and overall. Since subjects were asked three one minute questions on the first half of the clock and three one minute questions on the second half of the clock, it was possible to measure conjunction use on each side of the clock. Percentage occurrence is shown for times on the first half of the clock followed by those on the second.

For target times of five minute points on the first half of the clock, including the half past, the majority of subjects used the "past" conjunction to refer to time, in fact over 60% in all five minute point cases, and in comparison very few (around 20%) used the "to" conjunction. At the 35 and 40 minute points more subjects were still using "past" than "to", though the difference was small, and for the remaining five minute points of the clock "to" was used more often than "past". In response to one minute questions, the preferred conjunction was "past", irrespective of which side of the clock the minute hand was positioned. Incidence of digital reference to time and the use of o'clock were both very low throughout the spectrum of times, and they changed little. Thus the two halves of the clock are being distinguished by readers, but only when read to the five minute level, not to the one minute level.

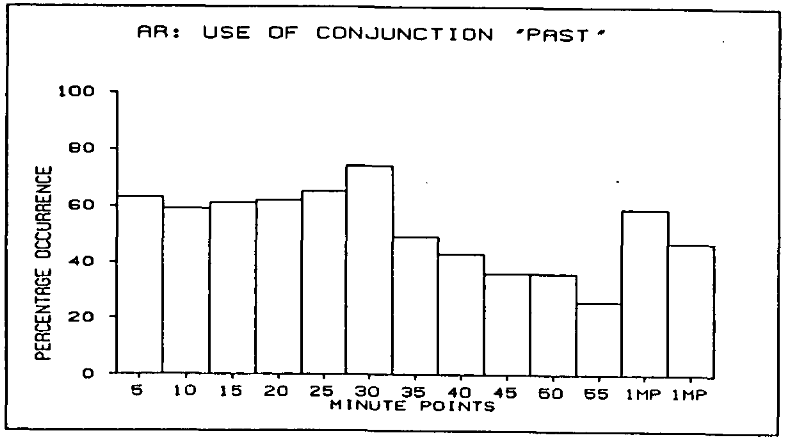
3.3.2.3 Conclusion

Thus although there are some differences in the way in which children respond to the various five minute points around the clock face, the magnitude of these is too small for them to be considered significant differences. Since the variety of stimulus times does not seem to account for the difficulty that the subjects experienced in reading analogue time, the features of the analogue display of time that cause the immature analogue time reader to be confused remain to be highlighted.

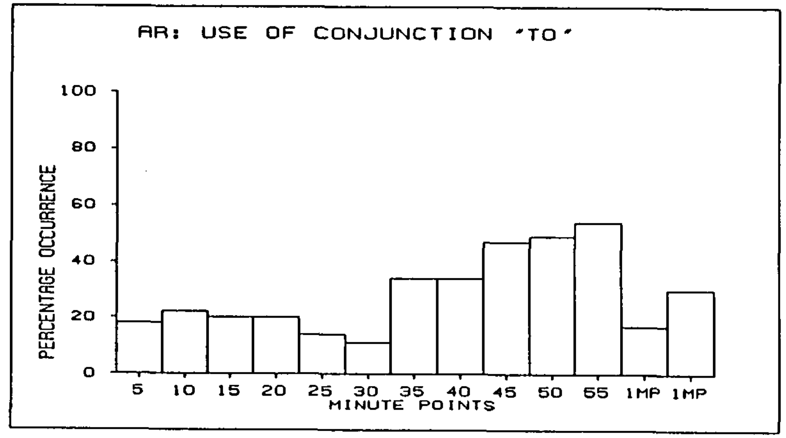
3.3.3 The Problematic Features Of The Analogue Display Of Time

3.3.3.1 Introduction

A close look at the analogue timepiece reveals a large number of



3.41



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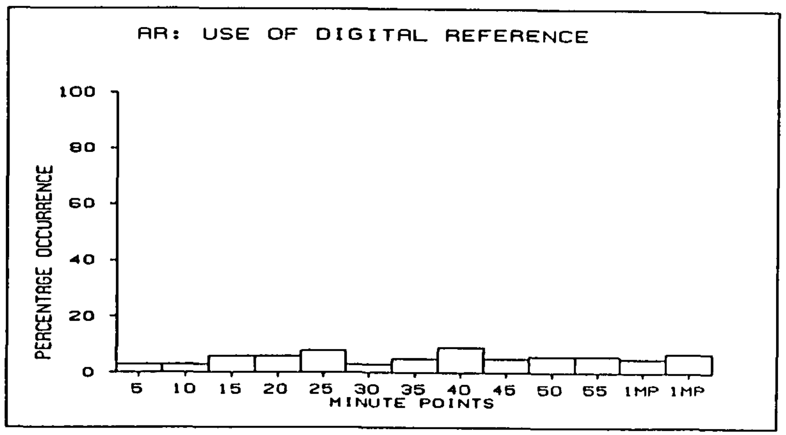
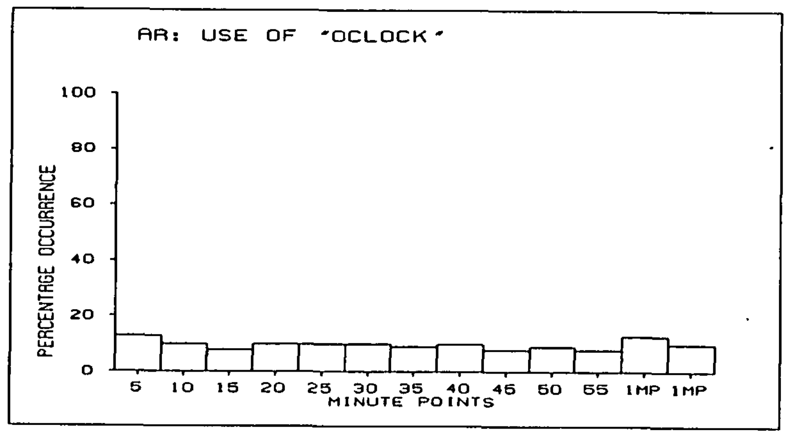


3.43



3.44

possible sources of confusion. In order to read analogue time satisfactorily, a child must realise that 1) time consists of an hour and a minute component, 2) these are indicated by two hands, and the numbers shown by each hand must be correctly assigned to the minute or hour component, 3) two metrics are measured on one surface, each of which must be mapped on to the number indicated by the appropriate hand, 4) the minute metric number must be calculated as it is not given, 5) the hour metric is not unambiguously indicated but must be judged according to proportional information and is not independent of the conjunction used to express time, and lastly 6) there are many different ways of referring to time, and the use of these must be properly integrated.

Appendix VII shows the whole range of errors observed in response to reading analogue time. The major misunderstandings in response to five minute questions, which were highlighted by the coding system, are presented on figure 3.45. An overview of the causes of confusions and their resulting errors are discussed below. Percentages given refer to five minute questions only.

3.3.3.2 Forming An Hours-And-Minutes Relationship

In reading analogue time a child must first realise that there are two components to the time, an hour and a minute component. Very few subjects (only 4%) failed to recognise the existence of two components, A possible example would be to give a single answer such as "60". Some children had appreciated the necessity for two components but had not attributed one to hours and one to minutes, an example of this might be a response of "60 and 30" to a time of 3:30.

3.3.3.3 Assignment Of Hour And Minute Labels

Even when the necessity for the formation of an hours-and-minutes relationship has been recognised, the correct use of these labels is clearly not an easy task.

There is a potential confusion in correctly assigning the hours and minutes to the two hands. Sometimes hours and minutes would be reported but the child would have failed to take notice of the

Group		Hour Errors	Minute Errors	Minute hand used for hour response number	Minute metric used for hour response number	Hour hand used for minute response number	Hour metric used for minute response number	Minute hand used for hour response number & hour hand used for minute response number	Minute metric used for hour response number & hour metric used for minute response number	Computational error of 1,2,3,4 or 5 minutes in calculating the minute response number
ALL SUBJECTS	Average % occurence per child	33	69	33	2	11	24	14	3	0
	% of children in which error occurs	50	81	47	7	45	31	34	16	0
	Average % occurence of error in those children who exhibit it	24	42	26	8	14	29	17	10	0
	% occurence of error	30	82	27	3	21	21	17	3	0
J3	Average Percentage per child	44	92	47	0	13	36	14	1	0
	% of children in which error occurs	90	98	85	8	58	45	48	10	0
	Average % occurence of error in those children who exhibit it	24	47	28	0	15	31	15	9	0
	% occurence of error	45	88	43	2	35	9	14	2	0
J1	Average Percentage per child	31	61	26	4	11	22	14	6	0
	% of children in which error occurs	13	78	55	10	38	33	40	23	0
	Average % occurence of error in those children who exhibit it	25	39	24	20	15	34	18	14	0
	% occurence of error	8	76	36	5	12	32	20	4	0
J2	Average Percentage per child	23	54	26	1	9	15	15	2	0
	% of children in which error occurs	48	68	3	3	38	38	43	15	0
	Average % occurence of error in those children who exhibit it	24	40	25	25	12	21	17	9	0
	% occurence of error	38	82	2	1	15	23	17	3	0

3.45 The Major Misunderstandings in Response to Reading Analogue Time on the Five Minute Points positions of the two hands, deriving his two numbers from the same hand twice. This error occurred in 40% of subjects, and the average occurrence in those subjects was 29% of the total errors they made.

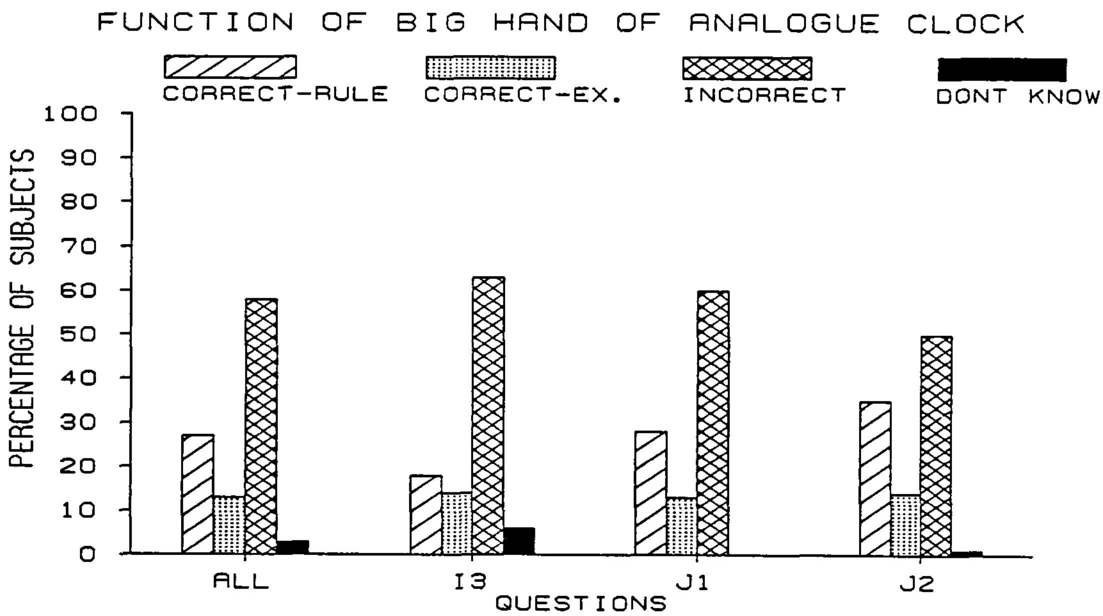
3.3.3.3.1 Reversal Of Hour And Minute Labels

One of the most frequent misunderstandings found was the tendency to read the number indicated by the minute hand as hours and the number indicated by the hour hand as minutes - a simple reversal of the hands. 38% of subjects were found to display this error and the average occurrence in these subjects was 27% of the total errors they made. Suggestions from teachers as to the cause of this error were split between two possibilities, the first, that it is a perceptual problem in which children *see* the hands incorrectly because the hands are not sufficiently different in appearance to be easily distinguished. Some weight is added to this as teachers report that as well as verbally confusing the hands, children also reverse the hand positions when drawing clocks. The other suggestion is that it is a problem of memory in which children incorrectly *remember* the functions of the two hands, attributing an indication of minutes to the hour hand and an indication of hours to the minute hand.

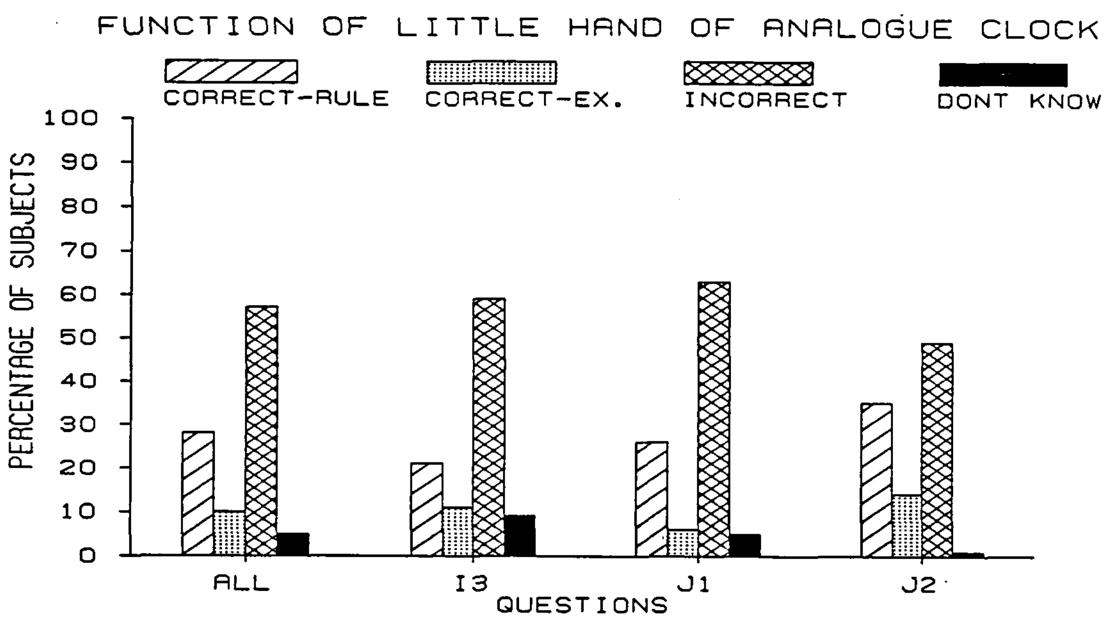
3.3.3.3.2 Reversal Of Hour And Minute Functions

To throw some light on this question, all subjects were asked the function of the big and the little hands during the test, figures 3.46-3.47 show their answers. They are clearly very unsure of the functions, with as many as 50% of the oldest children unable to correctly describe the function of the two hands.

Springer (1952) asked subjects the function of the hour and the minute hands. She dealt with four to six year olds and recieved similar answers to those recorded in this study. She found that an average of about a third of her oldest group of subjects were able to answer correctly or through some sort of example. This is similar to the data presented here for subjects of a comparable age.


FUNCTION OF BIG HAND OF ANALOGUE CLOCK
CORRECT-RULE
CORRECT-EX.
INCORRECT
DONT KNOW
PERCENTAGE OF SUBJECTS
100
90
80
70
60
50
40
30
20
10
0
ALL
I3
J1
J2
QUESTIONS

3.46


FUNCTION OF LITTLE HAND OF ANALOGUE CLOCK
CORRECT-RULE
CORRECT-EX.
INCORRECT
DONT KNOW
PERCENTAGE OF SUBJECTS
100
90
80
70
60
50
40
30
20
10
0
ALL
I3
J1
J2
QUESTIONS

3.47

3.3.3.3.3 Relationship Between Reversal Of Labels And Of Functions

Those children who reversed the functions of the two hands, that is, said the minute hand showed hours and the hour hand showed minutes, were investigated to see if these were the children who more often reversed the hands when reading analogue time. A T test was carried out, which was found to be significant, $T = 2.75$, ($p<.05$). Therefore, as expected, the children who exhibited confusion at the level of describing the function of the clock hands, also did so when required to read the clock.

3.3.3.4 Assignment Of Hour And Minute Metrics

One of the potentially most confusing features of the analogue clock is the existence of two metrics on one surface. The hour metric is immediately available but the minute metric must be calculated. There was a tendency amongst immature readers of analogue time to display an ignorance of the necessity to calculate a minute metric. Hence whilst recognising the need for an hour and a minute component and recognising that these are indicated by the two hands, the children used only the hour metric, so that eg. 9:25 would be read as "5 past 9". This occurred in 43% of subjects overall, and 58%, 33%, and 38% in each of the three classes, from infants to juniors. The average occurrence of this error in these subjects was 58% overall, and for subjects in the three classes, it was 63%, 69%, and 41% of all the errors they made. So there was a reduction in occurrence with age.

The use of only the minute metric was quite rare, in fact it was found in only 5% of children, and it formed 34% of the total errors of these subjects. It was also unusual to recognise the existence of two metrics but apply these to the two hands in reverse. Only 3% of subjects showed this error, but it accounted for 56% of all their errors.

Even when the basic skills required to read analogue time are understood and children are able to read the correct numbers from the correct hands using the correct metrics, there is still considerable scope for miscalculation, both on the minute and on the hour numbers.

3.3.3.5 Miscalculation Of The Minute Number

The minute number must be calculated through counting or by the application of a set formula whereby minute numbers are memorised according to their hour number positions on the clock face. Usually the pattern of counting is to count by fives for times on the five minute points, and by fives and then ones for times on the one minute point. This method allows for miscalculation by five minutes or by individual minutes, or by both. Children have problems with one to one correspondence between counting and pointing at each unit being counted and this is where the difficulties arise. Miscalculation of the minutes occurred in 16% of subjects, with an average occurrence in these subjects, of 21% of the errors they each made.

3.3.3.6 Miscalculation Of The Hour Number

3.3.3.6.1 Adjacent Hour Confusion

The hour hand on an analogue clock, not only gives information about the hour component of time, but also delivers information relating to the time past one hour and before the next depending on the proportion of the hour segment covered. If the hour hand is between two hour numbers, as it is in every case except for times on the o'clock, this situation is likely to be confusing to children. A confusion between the two hour numbers nearest to the hour hand is the single most often reported misunderstanding by teachers. In fact it did not seem to be the most common error, but is probably a particularly salient one.

Intuitively it would seem that the nearer to the following hour, the hand moves, the more likely it is that children will use that hour. The coding system will allow for the future calculation of how many of the wrong hour mistakes involve the use of an incorrect hour number nearer to the hour hand than the correct hour number, and how many invlove the use of an incorrect hour number further from the hour hand than the correct hour number.

3.3.3.6.2 Integration Between The Hour Number And "Past" And "To"

The necessity for integration between the hour number and the use of "past" or "to", leads to confusions. The most common past/to confusion appeared to be the case in which the minutes are counted as minutes past, but the higher hour and the "to" conjunction are chosen because the minute hand has been recognised to be on the second half of the clock. Thus 6:35 would be read as "35 minutes to seven". The full range of past/to confusions can be seen in figure 2.10.

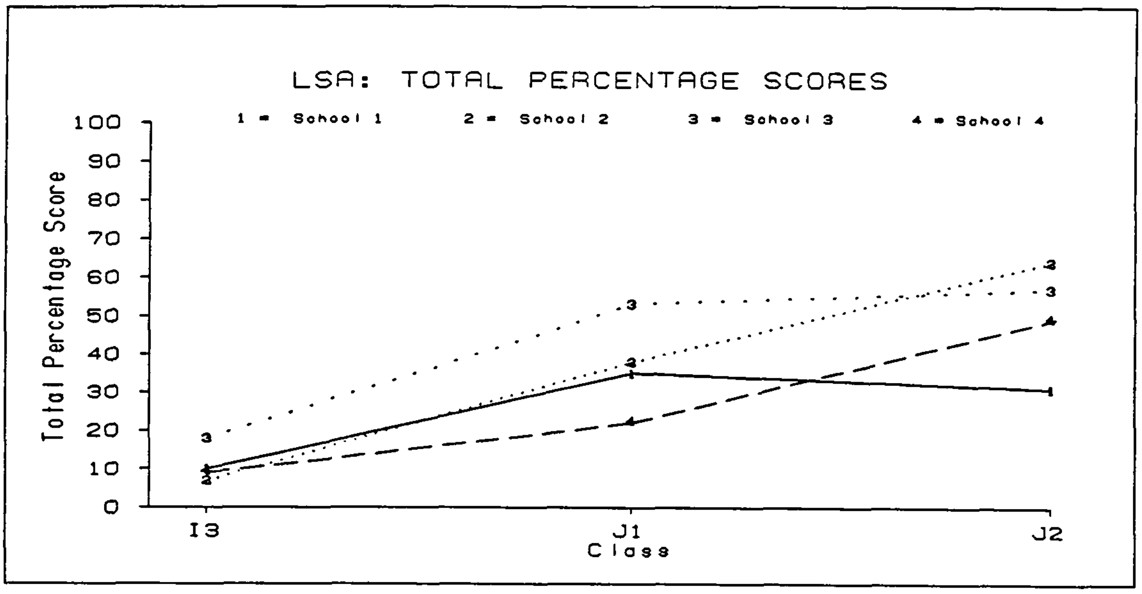
3.3.3.6.3 The Proportional Information Of The Hour Hand

That children are not in fact responsive to the proportional information contained in the exact position of the hour hand is obvious when their responses to setting analogue time are analysed. An understanding of the proportional information contained by the hour hand is a very rare occurrence indeed. Only 5 children out of the 120 subjects were found to be deliberately setting the hour hand in the correct position. Surprisingly these children were spread throughout the three age groups, and were not confined to the highest scoring subjects, which suggests that this is not an understanding which develops with age, within the ages examined, or with ability to tell time. It is unclear whether those children who had this knowledge had been given it or had worked out the proportional relationship between the hands themselves.

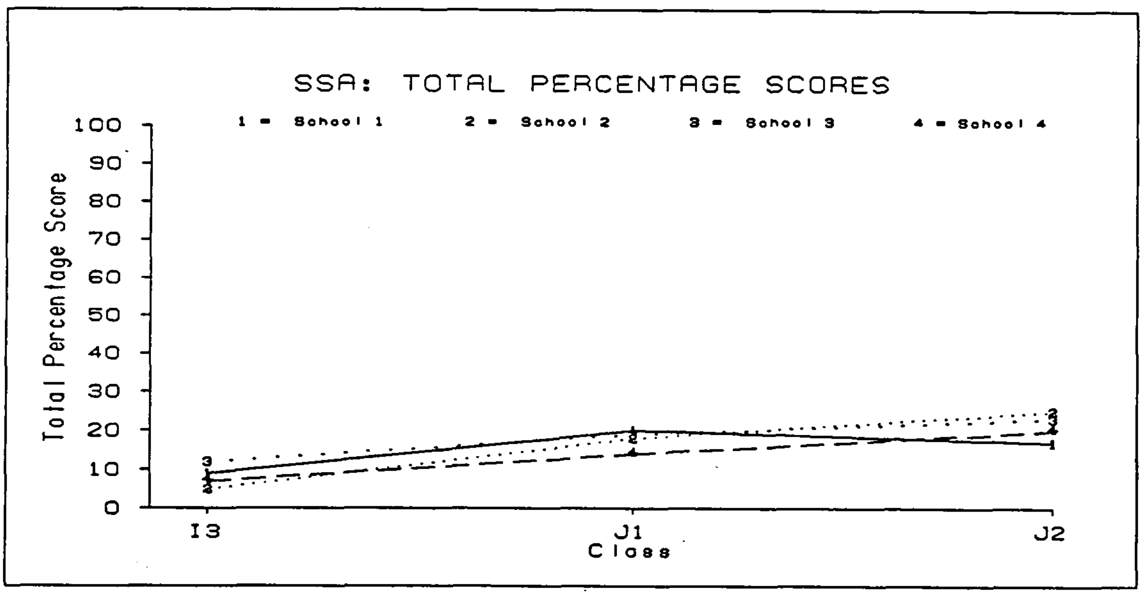
The widespread occurrence of this error is evident from a comparison between children's performance in setting analogue time when marked according to lax and strict criteria (figures 3.48 and 3.49). For strict criteria no allowances for incorrect positioning of the hour hand are made, unlike for the lax criteria, and the consequence is an enormous reduction in scores attained.

The application of strict marking criteria on the scores had a drastic effect on subjects of all three age groups, so that the highest total score score observed was only 25% in the second year junior class of School 2. This large reduction in scores indicates children's inattention to the exact position of the hour hand during setting, it shows their ignorance of it and explains their failure to make use of it when reading analogue time.

If lax and strict scores for setting analogue time on the o'clock,



3.48 Graph of the Total Percentage Scores for Setting Analogue Time (Marked According to Lax Criteria)



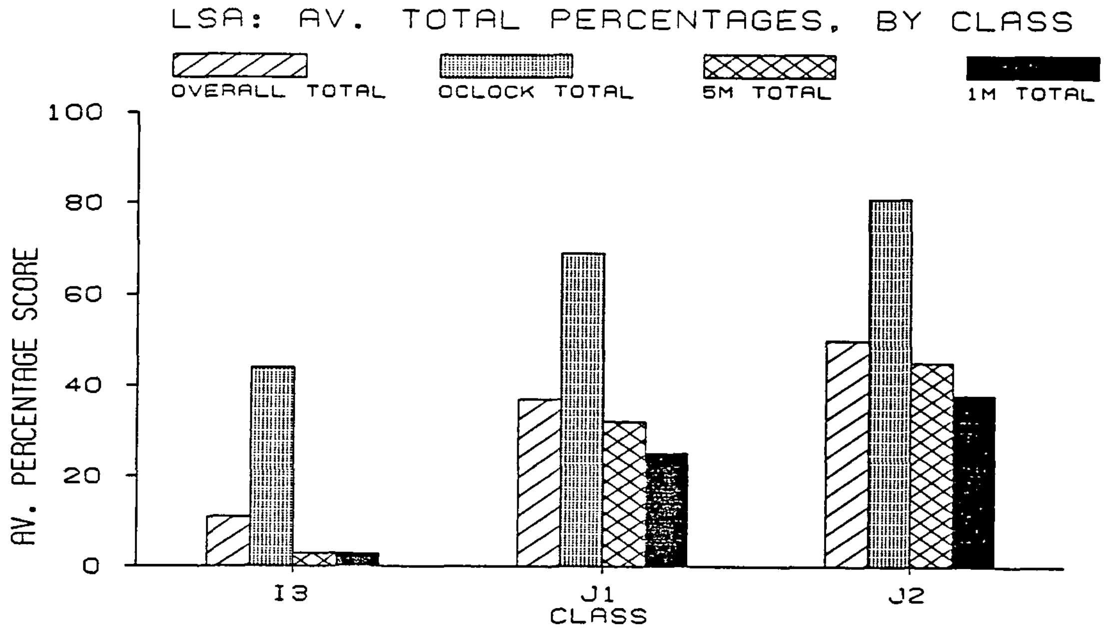
3.49 Graph of the Total Percentage Scores for Setting Analogue Time (Marked According to Strict Criteria) five minute and one minute points are compared (figures 3.50 and 3.51), the situation is clarified, since it can be seen that although there is a reduction in o'clock score, it is very slight. The main effect of the imposition of strict criteria has been to drastically lower the scores for the five and one minute questions. Since the position of the hour hand directly on the hour number is correct for o'clock questions, it was to be expected that these would not be affected at all by strict marking. The enormous reduction in scores on the second and third parts of the test, serves to confirm the widespread occurrence of incorrect setting of the hour hand directly on an hour number.

3.3.3.7 Variations Used To Express Time

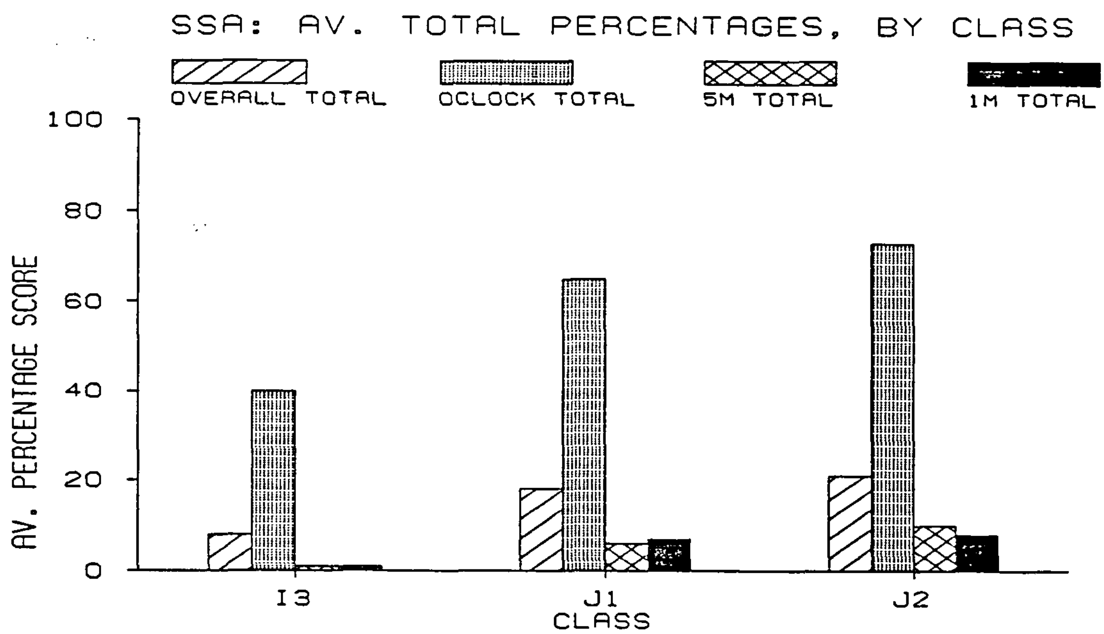
A particularly striking feature of analogue time is the large number of ways in which a time can be expressed verbally, for example 6:45 can be read as "6:45", "45 minutes past 6", "15 minutes to 7" or "quarter to 7". Although the problem of confusion resulting from this situation is often acknowledged in the literature, teaching programmes practised in schools tend to be less careful about how many variations of time are introduced at once. Often fractional terms are used first, even though children do not necessarily have the underlying concepts of fractions, and these are followed closely by "minutes past" and "minutes to" in many cases, and now with the increasing importance of digital time, the digital variation is often used as well. Certainly when children are exposed to time language outside the school environment, all the variations will be present. For this reason, it is not surprising that confusions result.

Figures 3.52-3.54 highlight the problems of entertaining multiple formats. They show the use of conjunctions by subjects in each class for questions on the five and one minute points. Since subjects were asked three one minute questions on the first half of the clock and three one minute questions on the second half of the clock, it was possible to measure conjunction use on each side of the clock. Percentage occurrence is shown for times on the first half of the clock followed by those on the second.

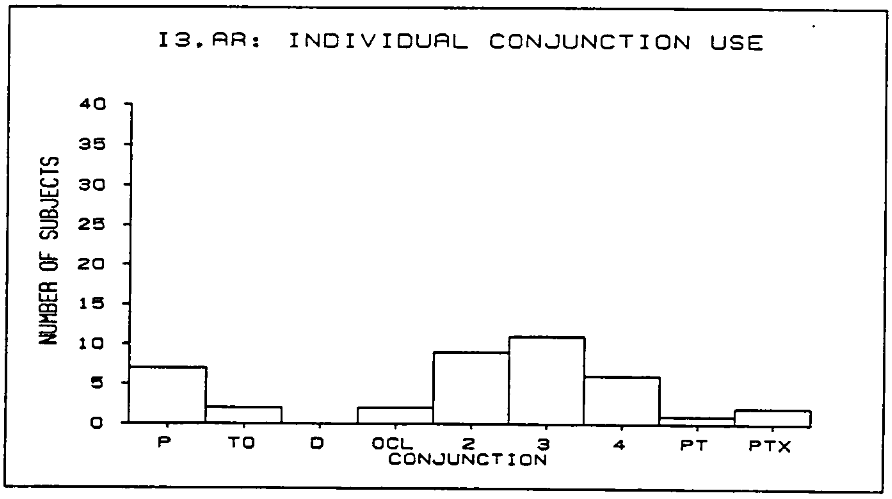
It can be seen that many children are attempting to use a number of



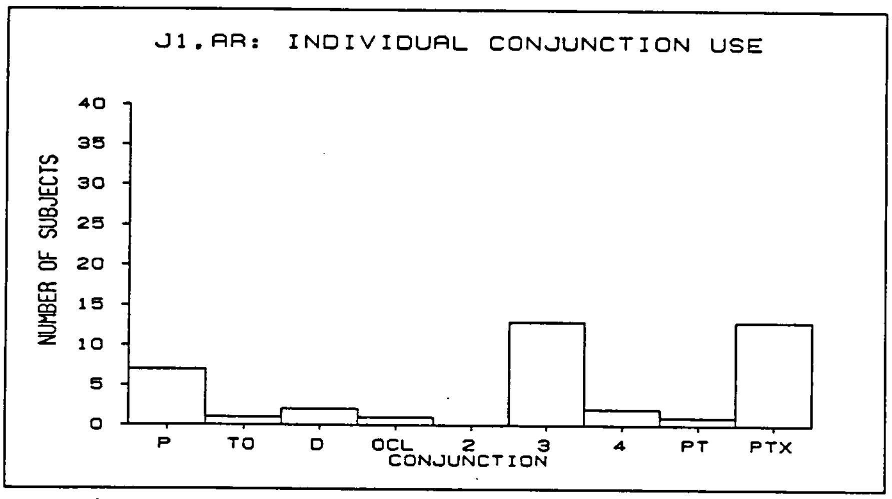
3.50 Average Total Percentages, by Class, for Setting Analogue Time (Marked According to Lax Criteria)



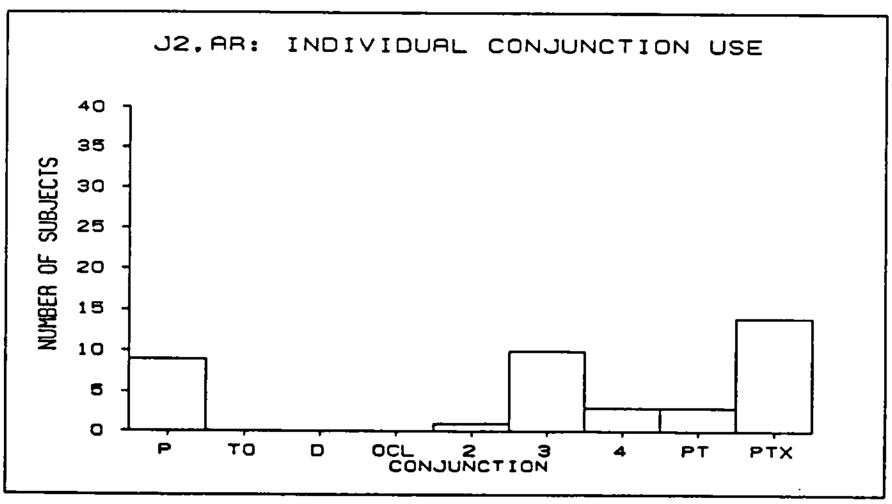
3.51 Average Total Percentages, by Class, for Setting Analogue Time (Marked According to Strict Criteria)


I3.AR: INDIVIDUAL CONJUNCTION USE
NUMBER OF SUBJECTS
40
35
30
25
20
15
10
5
0
P
TO
D
OCL
2
3
4
PT
PTX
CONJUNCTION

3.52


J1.AR: INDIVIDUAL CONJUNCTION USE
NUMBER OF SUBJECTS
40
35
30
25
20
15
10
5
0
P
TO
D
OCL
2
3
4
PT
PTX
CONJUNCTION

3.53


J2.AR: INDIVIDUAL CONJUNCTION USE
NUMBER OF SUBJECTS
40
35
30
25
20
15
10
5
0
P
TO
D
OCL
2
3
4
PT
PTX
CONJUNCTION

3.54

methods of expression of time at the same time, without any reasonable strategy in their application. With increase in age, the number of variations decreases slightly, but more marked is the better application of these strategies.

3.4 CONCLUSION

Children's scores on the tasks presented in this study are poor. The nature of their errors reflects a great range of possible types of confusion, originating from the features of our time measuring devices. Thus a large part of the difficulty children experience in attempting to decode clocks can be attributed to features within the design of these systems of measuring time.

CHAPTER 4: DISCUSSION

4.1 TEST PERFORMANCE

4.1.1 Overall Performance

The most striking feature to emerge from an analysis of children's time telling abilities is their low level of performance. Even children in the second year of junior school scored only 68.3% correct overall on digital reading and 44.0% correct overall on analogue reading. They correctly answered 97% of o'clock questions, 80% of five minute questions and 77% of one minute questions when reading digital time, and the scores were only 98%, 51% and 33% respectively for the three parts of the analogue reading test. Moreover, only 25% of J2 subjects completed the digital reading test without errors, and this figure was only 5% on the analogue reading test.

This seriously challenges the traditional view that time telling skills are almost fully developed by the middle junior school years or even before. The even lower attainment levels for setting time of both representations adds weight to this, suggesting that true understanding of time measurement is in fact even less developed than would appear from attention to reading scores alone.

4.1.2 Relative Order Of Performance Of Skills

Subjects scored higher on reading time than on setting it, higher on reading digital time than reading analogue time, and higher on setting analogue time than on setting digital time. From the pattern of response, a hierarchy of skill acquisition can be tentatively proposed.

4.1.2.1 A Comparison Between Reading And Setting Time

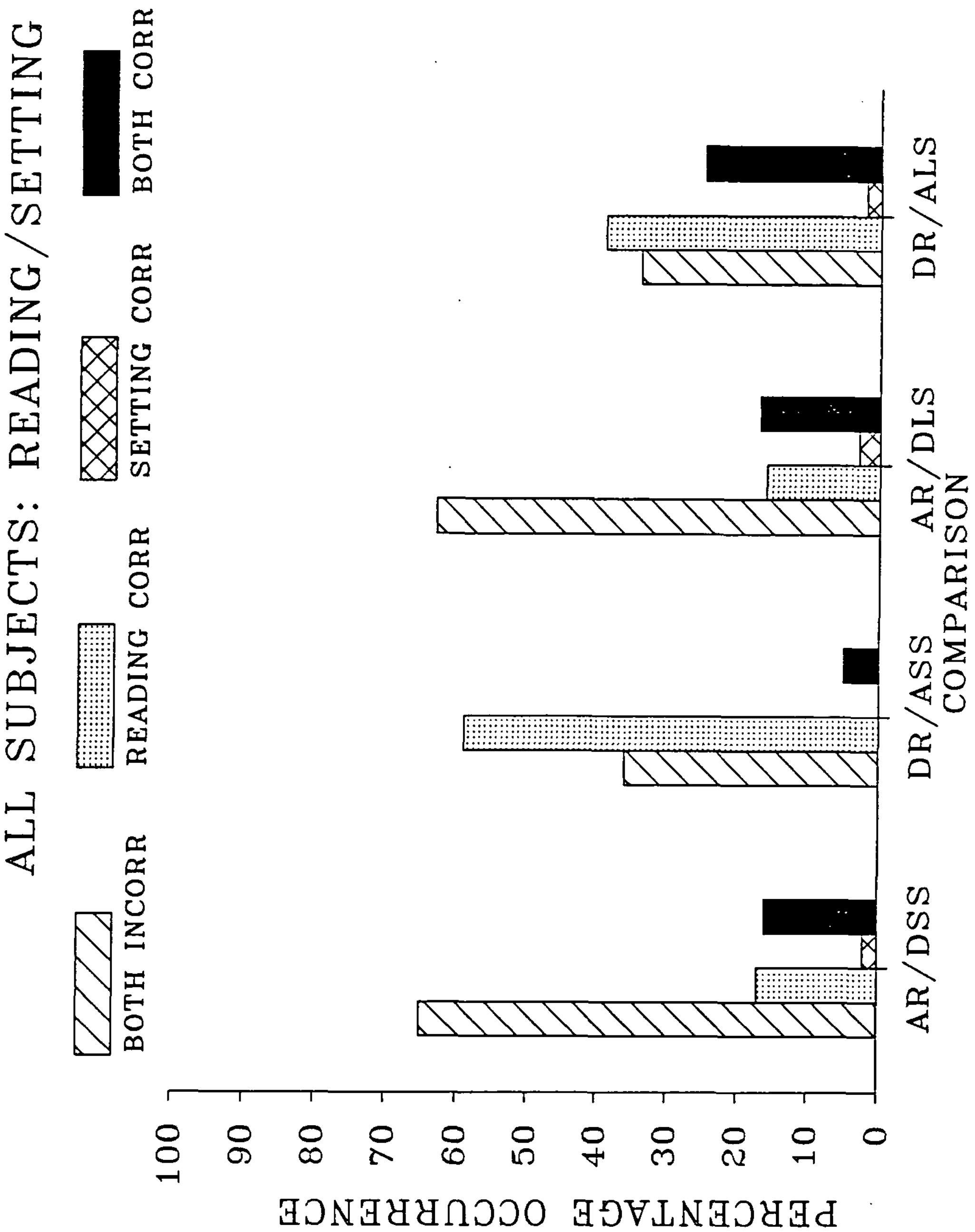
That setting scores are much reduced compared to reading scores, suggests that the setting of time is a more difficult task than the reading of time. However, reservations are held about this as in the present educational environment there is more emphasis on reading than setting, so that the effect observed may be due, in part at least, to the less familar nature of the setting task, compared to that of reading.

The only two researchers to consider the relative order of development of ability to set a clock, are divided on this issue. Springer (1952) had subjects read and set a small number of times and found that they read time better than they set it. On the other hand, Reisman found, using Bruner's enactive level of learning, that children can reproduce time on a clock better than they can identify it and so concluded that the ability to set time precedes the ability to read it.

To examine further the relationship between reading and setting time, data for all subjects has been organised to show the percentage occurrence of - answering both the reading and the following setting question incorrectly, answering correctly only the reading question, answering correctly only the setting question, and lastly answering both the reading and the setting question correctly (figure 4.1).

One of the most noticeable features of this data is that a correct response to setting time occurs on very few occasions when not preceded by a correct response to reading time. This is not surprising since in the test, the stimulus for setting comes from the target time given, but only *after* this time has been read. Thus setting is a two stage process and response can be affected by either the target time or the reading response given. Although emphasis was placed on setting the clock to the *same* time as the stimulus clock, the effect of the time previously read from this stimulus clock, could not wholly be dispelled. This is a second reason why a claim that the ability to set time develops later than the ability to tell time, must be viewed with reservation.

The design of a more appropriate empirical approach than that of the present test, will be necessary to tease out the developmental sequence of these two accomplishments. For example, it would be possible to look at whether subjects who both read and set time incorrectly, actually set correctly the time they had read.


ALL SUBJECTS: READING/SETTING
BOTH INCORR
READING CORR
SETTING CORR
BOTH CORR
PERCENTAGE OCCURRENCE
100
90
80
70
60
50
40
30
20
10
0
AR/DSS
DR/ASS
AR/DLS
DR/ALS
COMPARISON

4.1

4.1.2.2 A Comparison Betweeen Reading Digital And Analogue Time

The total scores for reading analogue time are noticeably lower than those for reading digital time. The magnitude of the discrepancy between the two, suggests that fluency in reading analogue time is about a year behind that for reading digital time.

Since the emphasis of teaching is on analogue time rather than digital time, this effect cannot be said to be due to children's exposure to time at school. It is more likely that the prevalence of digital time on items around the home, such as video recorders, and the easier nature of the task itself, are responsible for this effect.

That children had a greater knowledge of the digital clock than of the analogue clock was supported by the fact that questions concerning the functions of the sides of the digital clock were more often answered correctly by subjects than those concerned with the functions of the hands of the analogue clock (44% as opposed to 39% correct). This is surprising as one might think that the two hands of an analogue clock, because they tend to be emphasised so much more in classroom teaching, would be easier for the children to give a function for, than the sides of a digital clock.

4.1.2.3 A Comparison Between Setting Digital And Analogue Time

Subjects performed slightly better on analogue setting than on digital setting when both lax and strict criteria for marking were used. An inference that the skills involved in setting analogue time develop before those for digital time is only speculative, because of the reliance of setting one representation upon reading the other. However there is some support for this order of development from teaching, since less emphasis is placed on the digital clock than the analogue clock, and while the analogue clock is set only occasionally, the digital clock is never set, in most classes. This may be because teachers are lulled into a false sense of security, believing that children know more than they actually do about digital time, and whilst the effect is not noticeable on digital reading, because of the much easier nature of the task, it is considerable on digital setting.

4.1.2.4 Suggested Order Of Development Of Skills

The order of development of the four skills therefore implied, is digital reading, analogue reading, analogue setting, digital setting. It is thought that digital time can be read quite easily, without much depth of knowledge of time, so that ability to set digital time would develop considerably later than ability to read it. Whereas a considerable understanding of analogue time is required before it can be read, so that the ability to set analogue time is likely to follow reading ability quite closely.

4.1.3 Errors

Another particularly important finding of this study has been the exposure of an incredibly large number of types of misunderstanding that occur when children attempt to read or set a digital or analogue clock. In the light of this, it is no longer possible to discuss children's errors on these tasks as simply "wrong". Instead it is necessary to highlight the causes of these misunderstandings and work on producing effective avoidance and corrective techniques.

Some of the most common errors when reading digital and analogue time have already been highlighted through an examination of the data. A more detailed taxonomy of error types can be found in appendix VII though it is likely that further work is required before it is complete.

4.2 EXPLANATIONS FOR POOR PERFORMANCE

4.2.1 Testing Procedure

One possible explanation for the poor performance of subjects, would be that the test is not, in fact, satisfactorily measuring the ability to tell time. This is not thought to be the case since much care was taken over developing a test designed specifically to measure time telling ability effectively. In addition, the test has been proved to be reliable.

A more likely explanation is that development of these skills in children actually takes place over more years than is traditionally thought, and in fact continues well past the second year of junior school.

4.2.2 Anxiety

Anxiety is always a problem when interviewing and testing subjects, especially if the topic is unfamiliar, since lack of confidence in ability will tend to increase anxiety. Levels of anxiety in response to the test situation could not be measured formally and accounted for within the scope of this study. However, an attempt was made to minimise potential anxiety levels. Instead of taking subjects out of the classroom to be tested in a separate room, the tests were carried out in a corner of the classroom to maintain continuity of environment. Also, much care was taken on the part of the experimenter, to introduce herself and explain that the purpose of the study was to understand what is difficult about telling the time, rather than to evaluate the performance of individuals. Thus anxiety was not thought to be a major contributing factor in the resultant low scores.

4.2.3 Experimenter Characteristics

Since a comparison of results obtained on the test by the experimenter with those obtained by another tester found no effect of experimenter characteristics on results, this must be rejected as a contributing factor in the low scores obtained.

4.2.4 Sources of Difficulty Within the Test

Detailed analysis of the misunderstandings and performance of subjects when reading time has exposed the extent of inherent pitfalls in the design of our time measurement devices. For both digital and analogue time, the o'clock questions were more often answered correctly than the five or one minute questions. In addition, children were significantly better at answering five minute questions than one minute questions when reading analogue time.

There was little difference in the percentage of correct responses to each of the five minute points of the digital clock, and although a more substantial difference was found with regard to analogue time, this was not a significant effect. Hence the five minute points of the clock, with the exception of the o'clock point, are considered to a uniform stimulus.

In order to read time, a child must first understand the nature of the task, that he is required to report an hours-and-minutes response. After this there are a number of confusions which can cause the response to be incorrect. For both digital and analogue time, there can be confusions between hours and minutes, and between "to" and "past". In digital time, the digits can be reversed and in analogue time the metric can be reversed. In both representations numerals can be misread. In analogue time, miscounting accounts for many of these errors.

This goes some way towards accounting for the poor scores recorded, but does not seem to form a complete explanation. For this reason, it is necessary to examine the nature of the environments in which time telling occurs, to see whether there are problems at the home, school and class levels, in addition to potential sources of confusion at the level of the task.

4.2.5 The Home Environment

A child's preschool experience and home environment are particularly difficult to measure accurately and certainly cannot be measured to any great degree in a study of this scope. Nevertheless, experiences of time that occur at home, prior to, and during, the school years obviously have very important influences on understanding of the concept of time and the ability to tell time. For this reason, an attempt was made in this study to supplement the main test data with information on the home environment. This consisted simply of children's answers to questions about whether they possesssed a watch and whether there was a clock in their bedroom. Figure 4.2 shows subjects' answers to these questions.

Nearly 80% of subjects in each class had a watch or a watch and a clock, so that their exposure to time was thought to be considerable. Of the remaining subjects, a surprising 14% of children had no timepiece at all. Although children in this category are not evenly distributed, they are not confined to the economically poorer schools, and in fact can be found in all schools studied. An effect of age was observed, in that between the first and second year juniors there was a large increase in the number of children with access to a clock.

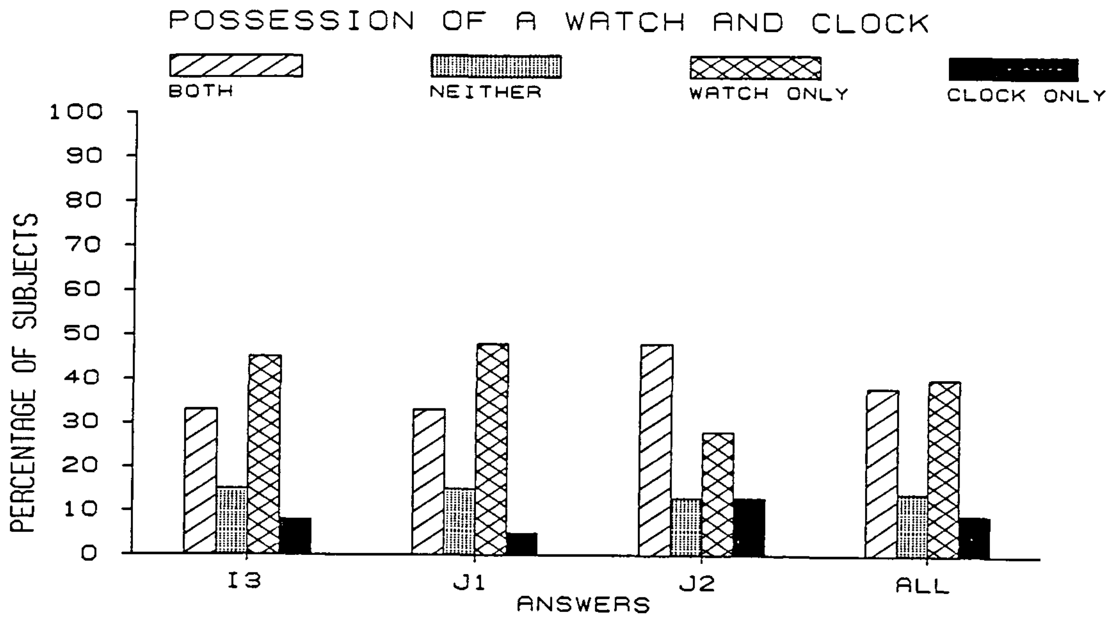
In the matter of clock and watch types, little effect of either class or school was observed. Figure 4.3 shows that overall, exactly the same percentage (33%) of children possessed a digital watch as an analogue watch. A surprisingly large number of children did not have a watch at all (23%) but included in this were the children who had broken watches, who could not be said to have been exposed to time through this medium. This inclusion seemed reasonable since the reasons for breakages were varied and not dependent on any feature of the child or watch. Only (12%) of children had both a digital and an analogue watch.

The exactly equal incidence of digital and analogue watches should go some way to dispelling the widespread assumption that most children have digital rather than analogue watches, because they are cheaper. It is more likely that parents believe analogue watches to be better for teaching and learning, than digital watches, so buy these.

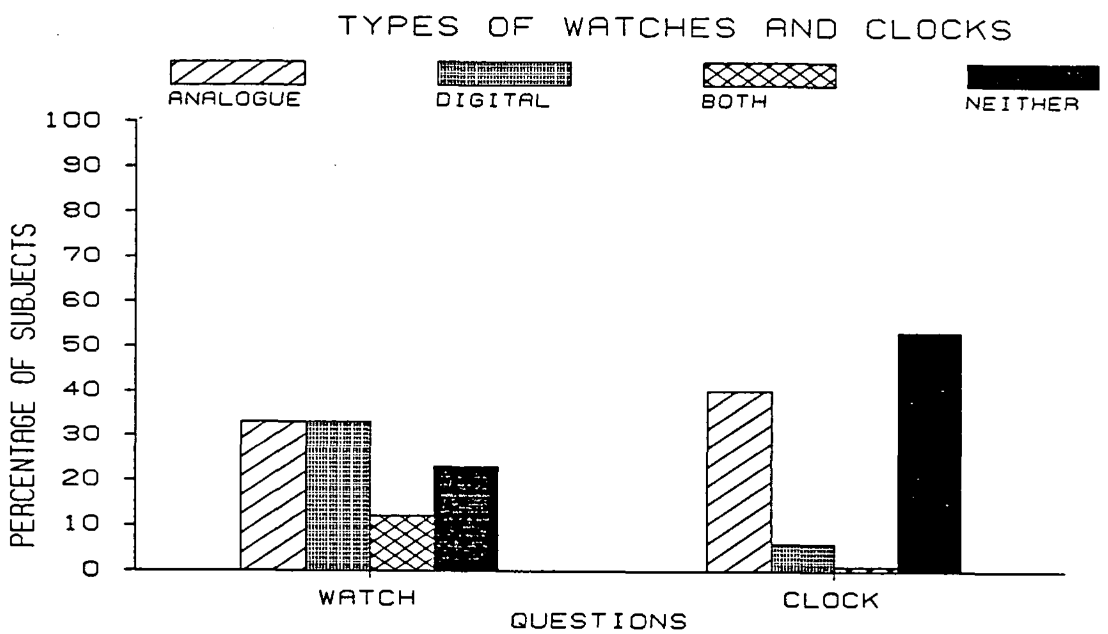
The distribution of reported access to clocks was much less even (figure 4.2). The majority of children, an enormous 53% did not have a clock in their bedroom. Most of the remaining children had an analogue clock (40%), only 6% had digital clocks and a tiny 1% had both.

Pooled twosample T tests were carried out to examine the effect of possession of a watch, and access to a watch, on total score, for each class. In all cases, both factors were found to be non-significant.

This would seem to suggest that these factors of the home-based environment have little effect on time telling development. However, in the majority of cases, children were not wearing their watches when tested, so it is not surprising that the benefit of the possession of a watch in practical terms to the richness of their time telling


POSSESSION OF A WATCH AND CLOCK
BOTH
NEITHER
WATCH ONLY
CLOCK ONLY
PERCENTAGE OF SUBJECTS
100
90
80
70
60
50
40
30
20
10
0
I3
J1
J2
ALL
ANSWERS

4.2


TYPES OF WATCHES AND CLOCKS
ANALOGUE
DIGITAL
BOTH
NEITHER
PERCENTAGE OF SUBJECTS
100
90
80
70
60
50
40
30
20
10
0
WATCH
CLOCK
QUESTIONS

4.3

environments was limited. Also, although the presence of a clock in the child's bedroom may give some indication of the state of the home environment with respect to time, it is unlikely to be an exact reflection of the situation.

The school and class time telling environments, because of their greater accessibility, can be more accurately assesssed. The survey of current teaching methods and environment through observation and discussions with teachers and mathematics co-ordinators, and the review of software undertaken in this study, go some way towards providing this information.

4.2.6 The School Environment

Through interviews with the mathematics co-ordinators of each school, information was gathered concerning the ways in which mathematics teaching is organised at a school level.

4.2.6.1 Mathematics Policy

The basis for teaching a major curriculum subject like mathematics, should come from a school policy which outlines what is taught of that subject, at each age level. Only School 3 had a mathematics policy and this was described as an unwritten, implicit set of principles.

The mathematics co-ordinators of the remaining schools said that the construction of a mathematics policy was planned and that it would include time. The competing priorities of the curriculum and the imminent publication of the National Curriculum were blamed for the lack of policy. Schools 2 and 4 said that mathematics teaching in their schools at present, was guided by their mathematics scheme.

Thus the teaching methods and content is left largely up to the discretion of individual teachers, and therefore may vary widely. This suggests that continuity of teaching throughout schools may be deficient. For this reason, mathematics co-ordinators were asked about integration.

4.2.6.2 Integration

The integration of teaching across classes would seem to be an important factor in efficient learning. Schools 2 and 3 said they had very little integration. Schools 1 and 4 said that some integration was provided through the scheme, although it was acknowledged that schemes can only provide integration if well used.

In School 4 discussions between teachers, especially when planning ahead for the coming year, and use of experience of children's capabilities at different ages, were mentioned as aids to integration. Flow diagrams of each teacher's topic for the term are displayed on the staffroom wall in School 3, so that teachers will know what is occurring in the rest of the school. In School 2, records of pupils' progress in the scheme are kept and carried up the school, but as teachers do not always follow the scheme sequentially, it was pointed out that these are not exact records of what a child has covered.

Integration was agreed by three of the interviewees to be difficult to achieve in practice as teachers are teaching as individuals in separate classes, and sometimes even in separate buildings, so that sequential classes do not often meet, and there is limited exchange of ideas. The heads of Schools 2 and 4 expressed concern at the minimal level of integration, but stated that it will always be a problem as it depends on teachers' perspectives and expectations. Only a full review of the subject was thought to be likely to have an effect on the situation and this was rejected as too time consuming considering the small place in the curriculum occupied by time. However it was hoped by the Head of School 2, that the National Curriculum might revolutionise problems of integration, since it requires all teachers to follow the programmes of study. The mathematics specialist at School 1 said he did not think integration need be a problem if teachers all work together, and exchange ideas through conversation.

There is little conversation in the staffroom on particular curriculum subjects unless someone is doing a topic, or some literature for review has been sent to the school, as this tends to stimulate conversation amongst teachers.

Three of the interviewees thought that the integration of the teaching of time is desirable and important. The mathematics co-ordinator of School 1 did not support integration as he thought that it was important that children are given as many varied experiences as possible.

4.2.6.3 Schemes

The content of teaching was clearly much influenced by commercial mathematics schemes. When asked for their opinions of their chosen mathematics scheme, both generally, and with respect to time, the interviewees gave a wary response. They pointed out that all schemes have numerous gaps, so that they must be widely supplemented by a variety of sources.

The Head of School 2 criticised mathematics schemes for tending to contradict activity since it is activity through which children learn. At School 1 the danger that schemes might strangle maths teaching was mentioned, since children tend to charge through the workbooks, so they are all at different stages. This necessitates individual teaching for each pupil in a class, which is not a practical requirement.

However, it is acknowledged that schemes are a valuable teaching aid, good for ideas, structure and continuity. At School 2 the view was that there is a continuum from teacher-driven to scheme-driven and at either end there are problems.

4.2.6.4 Computers

The influence of technology on the curriculum is continually increasing and for this reason interviewees were asked about the available computing resources in their school. These varied from two computers in School 3 to six in School 2. All interviewees stressed that their present computer resources were not sufficient and that the ideal situation would be to have at least one computer per class. Some of the computer screens in one school were television screens as these are about half the price of a computer screen, but the display on them was not particularly clear. Some schools had printers, and concept keyboards, though the concept keyboards in School 4 were not in use as teachers did not know how to set them up or use them.

In all four schools the use of computers was determined by timetabled allocation, although this was flexible. Access to computers ranged from only two hours a week for class 2 in School 3 to almost a full week for the juniors in School 4. None of the mathematics specialists was aware of whether the school possessed any programs which included work on time.

4.2.6.5 Advice

None of the four schools had received any advice this academic year on teaching time and three had had no contact with a mathematics adviser at all. This lack of advice is partly due to a shift away from advisers towards inspectors, and partly because advisors only visit a school if their presence is requested, a regular visit is not automatic.

However all interviewees expressed a desire for useful information regarding the teaching of time. School 3 thought that a "Baker Day" would be useful, as well as discussions between staff about how they teach time.

The head of School 2 stressed that advice would be especially worthwhile if in the form of nationally published literature, for example, books of ideas, and government reports. The co-ordinator of School 1 said advice on activities giving different experiences to teach the concept of time and for investigating and using time rather than simply drawing clock faces, would be appreciated.

The Head of School 4 said he would appreciate advice on the receptiveness of children at different ages, and at what developmental point to start teaching the various aspects of time, such as analogue time, digital time, and the 24 hour clock. More concrete advice on methods to use, how best to introduce and develop the teaching of time, and some information on how these skills are acquired, would also be useful.

4.2.6.6 Recommendations

Lastly the interviewees were asked whether they had any recommendations for improvements in the efficiency of teaching time in their school.

The co-ordinator at School 1 said that teachers should be more aware of what their colleagues are doing, and resources could be improved, especially those for the teaching of the very early stages of learning about the concept of time.

The Head of School 2 stressed the need for teaching objectives for the understanding of time and said that the attainment targets of the National Curriculum should provide these. He said that the school mathematics scheme would have to be reviewed to ensure it complies with the National Curriculum requirements. Teaching can be improved dramatically by improving resources, including having clocks in the teaching area every day, of both analogue and digital form.

The co-ordinator of School 3 proposed that there should be a shift away from written work towards a general encouragement of time understanding across the curriculum, through practical first-hand experience of using clocks and engaging in a variety of activities, with much discussion.

The Head of School 4 suggested a thorough review of time to highlight areas of deficiency which could then be tackled.

4.2.6.7 Conclusion

So from talking to mathematics co-ordinators, the impression is one of little continuity or order in the teaching of time. Policies are changing, integration is a rarity, advice from external agents is non-existent, schemes are not an ideal basis for teaching, resources are deficient, and computers are used little, if at all since software is unknown. In short, the style of approach is far from ideal, and it is not surprising that in such an environment, children fail to flourish in developing time telling skills.

4.2.7 The Classroom Environment

To get a deeper understanding of what exactly occurs in the environment of the child, attention must be directed towards the comments of the class teachers when asked to explain the content and style of their teaching.

4.2.7.1 What Is Taught And When

4.2.7.1.1 General

Such a great diversity of aspects of time were covered by the classes observed in the study that it is not easy to summarize what was being taught. Generally the younger children were taught more about the concept of time, particularly the introductory aspects, such as day and night, the seasons, sequencing, etc. Some teaching of the concept of time did occur with older children, covering areas such as the calculation of duration, and historical time. There was a tendency to teach the concept of time before telling the time in the year, particularly to the infants, although teaching on the concept of time was often ongoing throughout the year.

Telling the time was taught in every class examined except one second year junior class where the teacher considered that children should have already mastered this skill (though the performance of his pupils on the test did not uphold this), hence he concentrated on aspects like the 24 hour clock and timetables. There was a huge variation in what was covered, though the analogue representation was clearly favoured over the digital, it was usually taught first and received more attention than digital time. Some teachers did not cover digital time at all, believing its introduction to be confusing when analogue time had not been fully mastered. In no class was digital time taught to the exclusion of analogue time.

All teachers followed the chosen scheme, some introduced the areas of time covered before they were reached by the pupils in their books, some taught them at the same time as the scheme work, and others relied more heavily on the scheme, only getting involved if a child developed problems. Schemes tend to provide one or two pages on one subject, like time, and then switch to another topic. This situation was criticised by teachers for failing to provide sufficient practice or reinforcement of the concepts learned. Although some teachers followed the scheme as it progressed, and were happy for children to pursue different topics in their books, depending on where they were in the scheme, others tried to supplement each topic or to select a number of areas on a topic from the scheme, to provide a sufficient amount of work to enable the whole class to learn about one subject together.

4.2.7.1.2 The Concept Of Time And Telling Time

All teachers agreed that some concept of time is required for a firm foundation before starting to tell the time, but it is something which develops over a long period of time.

It was felt by some teachers, that the relationship between the concept of time and telling time is predominantly in one direction, that if children understand the concept of time, they can understand telling the time. Children must have knowledge and understanding of the concept of time before reading time, otherwise the clock is meaningless, however, it is possible to tell the time without possessing a concept of time. A few teachers thought that there is an interactive effect between time concept and identification, that understanding of one builds on understanding of the other, and believed that if one is enhanced, the other would also be improved. Others thought of the two as separate, and not related in any way.

The concept of time and telling time are either taught together in parallel; or taught separately and later interrelated, in which case the concept of time is usually taught before the identification of time; or only one of them is taught at all. A few teachers did not have a deliberate policy on how to teach the concept of time and telling time. They varied their approach, sometimes teaching one before the other, but usually covering both at some point in the year.

Only one teacher said she only taught the telling of time, as she considered that the concept of time should develop naturally through conversation and experience. Only one teacher only taught the more advanced aspects of the concept of time and calculations involving time to his class of second year junior children, as he believed they should all have mastered telling the time, by this age.

Methods of relating the concept of time and telling time included an emphasis on discussion and practical activities rather than written work. Children can come to understand the relationship between the concept of time and telling time if instead of being told, they are shown, how the passage of time affects us, for example by watching plants grow, or looking at the seasons changing.

4.2.7.1.3 Analogue And Digital Time

About half the teachers said there was no difference between their pupils' familiarity with analogue and digital time, and the other half said that analogue tended to be more familiar. One teacher said he believed digital to be more familiar as parents find it easier than analogue time to teach. The children's familiarity with analogue and digital time had little affect on teaching.

More than half the teachers taught both analogue and digital representations of time. One did not teach telling time at all and the rest taught analogue time only.

However all the teachers interviewed thought that ideally children should be taught both digital and analogue time at school since both are present in the world. Although, since the teaching of the two representations of time at once might lead to confusion, one should be taught first, and only when children were confident with it, should the other be introduced.

Of those who taught both, some taught them together in parallel, using the understanding gained in one aspect to help with the understanding of the other. Other teachers taught analogue time, then digital time, then both, unless a child is poor at telling the time, in which case they tend to concentrate on teaching analogue time only. Most said they integrated the two in their teaching, often primarily because the mathematics scheme treated time in this way.

Others believed that knowledge of either representation does not affect the other unless children are able to convert them. One teacher said that ideally she would teach analogue time as minutes past all the way round the clock face, because it is easier to convert this to digital time.

Opinion was divided as to which of the two representations of time would be easier to learn about. One teacher thought that the familiarity of digital time would make it easier to learn about than analogue time. Some teachers believed that children attend more to analogue time as they consider it to be more difficult and are less familiar with it from home. One teacher thought that teaching analogue time is harder because children have an idea of time as digital. Other teachers said that learning digital time is more difficult than analogue time as digital clocks are difficult to manipulate and there are few other practical activities involving digital time.

Some teachers taught only analogue time because they thought that the introduction of digital time in addition to analogue, would be confusing, so should not occur until the end the second year or the beginning of the third year of junior school. One teacher said she taught analogue time only as she considered analogue to be the main method of representing time, and the clocks in school were analogue. She also saw analogue time as more difficult to teach than digital time and believed that children also think it is harder to learn, because of the fractions involved and the necessity of learning to map minute numbers on to the clock face.

4.2.7.2 How Teaching And Learning Take Place

Treatment of time seemed to vary every year, depending on the class involved and the importance placed on other areas of the curriculum. One teacher said that his method "differs every year, as I have not found a satisfactory way of teaching time".

A common approach to time is to teach it once near the beginning of the year, then leave a gap and revise it before the end of the year. Several teachers, even those of second year junior classes, said they did not worry too much if some of the children had not grasped what they had been taught in their class, as they knew they would be taught it again the following year.

Sometimes general teaching was supplemented by specific topic work. Only one teacher had done a class topic on time, and two said they would do a mathematics topic on time before the end of the year. The importance of the hidden curriculum was stressed by several teachers. It was clearly thought to play an important part in the development of the concept of time and the ability to tell time. For this reason teachers tried to use as many opportunities as possible for casual reference to time throughout the day, such as stressing the time of certain activities and asking children to perform tasks for specified periods of time. The importance of other curriculum areas, such as science and history, in aiding understanding of time was also mentioned.

In many cases the topic of time or some aspect of it, was introduced by means of class teaching, but some teachers dismissed this as a waste of time because of the wide variation in ability. Group teaching was the most popular approach, as it allows the level of teaching to be tailored to the pace and ability of a small number of children. All teachers stressed the value of teaching on an individual basis to deal with the problems of particular children as they occur.

It was thought that in the initial stages of learning about time, children generally pick up a sense of time through the order of their lives. Through everyday experiences time becomes meaningful. Thus parents and the home environment were thought to be a very important early influence. Children can benefit enormously from their parents spending time with them. Later friends and teachers have an increasingly influential role. It is also important that the home has a variety of clocks in it, so that children can become familiar with time and the way it is important in our lives. Children bring this wealth of experience into the classroom, where they encounter the more formal teaching of school.

The relation of daily activities to particular times and the teaching of the concept of time through easily assimilated events like the growing of plants, were thought to prepare the ground for more advanced concepts. There was a definite emphasis on the importance of practical work, especially with real clocks, and teaching through discussion, rather than simple repetition of written work. Also the regularity of the day and the extent to which it is governed by the clock, was said to be an important factor of the home and school environments.

Children are thought to learn time best when it is important and relevant to them. Time becomes relevant in situations like wanting to meet friends on time or wanting to see a favourite television programme and having to note its starting time. When children become involved in the measurement of time, they become sensitive to it. Many children *can* learn to tell time when it is not relevant, but others need this extra help.

Other factors considered to play a part in the development of time understanding were ability, concentration, effort, motivation, and maturity. Children must be ready for time, it must not be forced upon them too quickly.

4.2.7.3 Starting Point

Teachers either base their initial teaching level on the age of the children, or on the ability of the pupils with special emphasis on tailoring their teaching to the individual, or simply begin at the beginning and progress at a level appropriate to the particular children involved. Some teachers were very much opposed to the idea of basing teaching simply on the age of the children because ability can vary so widely within an age group. For this reason, most teachers seemed to favour trying to determine the level of the children and beginning there. Informal measurement of this level inevitably involves a certain amount of trial and error, whereby teachers simply start at what seems to be the most suitable point. It was stressed that it is important to find a level that does not overestimate the attainment of the less able children, to avoid causing discouragement. For this reason some teachers start at the beginning but quickly work up, progressing at the pace of their pupils.

Measurement of individuals was widely thought to be too time consuming to practice regularly, considering how small a part of the curriculum time is. No teacher was found to automatically test her pupils as a matter of course at the beginning of the year, but all did carry out some form of assessment prior to beginning to teach time. This was usually of a casual nature, most often through informal class discussion and asking children to identify time on a demonstration clock, though in one case it took the form of a few questions written on the board, and in another, workcards were used.

School records contain detailed information on attainment throughout the curriculum, usually including details of level reached in the mathematics scheme. This gives an idea of what has been covered, though not necessarily what has been internalised. Some teachers specifically said they referred to these records before beginning teaching, usually checking their reliability, and sometimes going back a step before beginning to teach.

Some teachers were more exact than others when asked about the range of ability of their pupils, but obviously since most lacked a definite testing procedure, any answer to this question could only be speculative. In spite of this they all agree the breadth of knowledge varies widely, that it can range from total naivety to complete understanding of analogue time, digital time, the ability to convert between the two, knowledge of timetables, calculation of duration, and the 24 hour clock. The general level of attainment was thought to increase with age, but the range to widen, as the progress of some children falls behind that of the average level for a particular age-group.

All teachers said they were careful to measure ongoing progress and levels of attainment, again usually informally through discussion and observation of how pupils tackled tasks they were given, including general classroom activities and scheme work, but also more formally through teachers own tests or check-sheets, scheme tests at the end of workbooks or topics, as well as standardized tests in School 2. Many teachers also make continual school records which are useful for their own reference as well as that of their sucessor.

4.2.7.4 Resources

4.2.7.4.1 Schemes

One scheme was used throughout each school, except in one school where a different scheme was used for the infants and the juniors. Teachers seemed to like the scheme they were using, although most were dissatisfied that it covered little on time. Two very definite criticisms were made about schemes.

Firstly, workbooks and textbooks are arranged so that there are one or two pages on one topic, then another topic is presented, so there are considerable gaps between work on a particular theme. This has several disadvantages, including the fact that the children will all reach a section on a particular topic at different times, so that an attempt to teach a certain topic to the class as a whole using the scheme is very difficult. Some teachers avoided this problem by spending considerable time and effort sorting out the scheme so that it could be used in topics, although they realised this was not the way in which the scheme was designed to be used.

Another unwelcome consequence of the nature of the presentation of the material within schemes, is that children are given little reinforcement of each topic and so quickly forget it, so that when they do come across it again in their books, they are unable to tackle it without problems. For this reason schemes need continual reinforcement.

The second criticism concerned the fact that schemes cover only the bare bones of the mathematics curriculum. This is because they are designed to stimulate additional work rather than set fixed prescriptions of what should be covered. Teachers said that they have to supplement the scheme with much other work because of the insufficient content.

Other criticisms included mismatches between the terms used to express time by the teacher and by the scheme, questions on time that are too advanced and so push children forward too quickly, and lack of practical work. Children need a lot of practical groundwork before starting to use workbooks in any area.

Thus in practice teachers used schemes as a base with the addition of more or less supplementary material, but were wary of the manner in which they used schemes. Material specified to supplement the chosen scheme included, ideas from colleagues, other schemes, books from school and home, workbooks, homemade and commercial workcards, duplicating sheets, and literature such as the Child Education magazine.

4.2.7.4.2 Clocks

An enormous range of types of clocks was encountered in classrooms, but the classes themselves varied from having good resources to very limited ones. One or two teachers expressed the view that few resources were of any help in teaching time. However, most teachers said they would welcome more resources.

Class clocks were available in only four out of the twelve classrooms. Two of these showed the time correctly, but one had stopped, and another was an hour slow having not been put forward when the hour changed. No working digital clocks were observed.

Most other clocks available in the class were ungeared. A large demonstration clock was common. Cardboard clocks, sometimes homemade, were also widely available, so that pupils usually had access to a clock at least between two.

Classes tended to have a poor selection of geared clocks for manipulation. Of the small number of geared clocks available, the majority of these were analogue, usually old broken alarm clocks. The few digital clocks that were available were often working clocks from children's own homes, so that they could be looked at, but not manipulated. School 1 had some commercial digital clocks with numbers on ribbons which could be wound to show the correct time.

4.2.7.4.3 The Computer

Teachers were also asked how, and to what extent, the important resource of computers is being used to supplement more traditional types of work occurring in the classroom.

There was a huge variation in available computer time, it varied from two hours a week to four days a week. However the majority of teachers had the use of a computer for between a third and a half of the week. A full day seemed to be preferred to the same number of hours, spread over several days.

The majority of teachers said their allocation of the computer was not sufficient. Those that did not complain pointed out that as there were so many other things to do, that the computer was not necessarily used all the time that it was available.

Those teachers who did not consider their allocation sufficient, all said they would like a computer permanently. One or two even went so far as to say they would like several computers, so that they could use several different programmes at once. However they stressed that just because they had a computer of their own, they would not necessarily use it every day. As one teacher pointed out, the advantage of having a permanent computer, is that it frees a teacher from feeling obligated to use it because it is her turn, rather than using it when it is relevant to what is happening in the classroom.

4.2.7.4.3.1 Software

Only four teachers said they had used the computer for work on time, and no teacher had access to more than two programmes on time. The universal reason for not using the computer as a resource when teaching time, was a lack of knowledge of programmes or availability of them in school. In addition, one teacher was also concerned about practical problems as she had 36 pupils. Two teachers said they might use the computers to teach time later in the year but had so far been concentrating on using it for other purposes. All teachers said they would use the computer for time if they had access to relevant programmes. No teacher had requested any additional software, perhaps they had not recognised the gap.

There were very few programmes available on time in the schools involved in the study. One or two teachers suggested that this was partly a financial problem as software is expensive. But there is also a more deeply rooted problem, that the topic of time is not a priority when choosing software, rather there is a bias towards language and more general areas of the mathematics curriculum.

Even when relevant programmes were available in schools, the teachers, and often even the computer specialists, were unaware of them, or unable to locate them. To some extent this is a communication problem between the teacher in charge of computers in the school and her colleagues. Two schools had no particular method of publishing the school's software. In the other schools systems of the display of information on available programmes were observed. One was a written catalogue system and the other involved the display and storage of all programmes along one wall of the staff room. Even these did not have the desired effect, since teachers in these schools were no better aware of software in their schools than other teachers.

Thus as well as a better selection of software, there is clearly a need for better publicity of what is available, to teachers within schools.

When asked what types of software concerning time they would like developed, on most occasions teachers suggested material that in fact already exists, thereby indicating that they were not fully aware of the range of software currently available.

Facilities for teachers to find out about programmes are limited. In the Durham area teachers are able to visit the LEA microtechnology centre to discover new programmes, discuss them and try them out, but this must be in their own time and therefore this opportunity is rarely taken advantage of.

A list of all programmes located on the topic of time, can be found in appendix VIII, a summary of programmes, in appendix IX, and a review of software is in appendix X.

4.2.7.4.4 Additional Resources

A wide variety of resources was used in addition to schemes, clocks and the computer, including transport and television timetables, sandtimers and stopwatches, clock stamps and templates, television programmes, wall charts, jigsaws of clocks, topic books, and games.

It was common for children to make time diaries of their daily schedule, and these stimulated much discussion and further work. Also, some teachers said they might make sand, water, fire and pendulum clocks. There were also the children's watches and that of the teacher. A teacher at School 1 had a very clear analogue watch of about 4cm in diameter, which she said she found very useful.

4.2.7.4.5 Resources Requested

The most frequently requested resource was clocks. Many teachers stressed the need for a wide range of real clocks, in all shapes and sizes, both analogue and digital, for children to manipulate, as well as a geared demonstration clock to show children how the mechanism operates.

A class clock was requested by all teachers who did not have one. Many of these teachers said they had already requested a class clock in school but had not received one. Some also called for digital class clocks. One interesting suggestion was a working clock for the "shop" in the corner of the classroom so that children could use the clock for practical purposes, to see what time the shop opened and closed.

4.2.7.5 Problems Of Teaching And Learning Time

All teachers agreed that time is a very difficult concept, both to learn and to teach, and that it is a subject that children generally find particularly difficult and often have a negative attitude towards. One reason put forward for its difficulty was the existence of two metrics on one dial. It was also suggested by one or two teachers that time telling is taught too early, that children do not have a sufficient concept of time before we begin trying to teach the identification of time, and that we push children on too fast.

Many teachers believed that learning to tell the time is more gradual a process than many other topics. Others stated that they thought there is a developmental point at which understanding of time telling 'clicks', after which very few errors are made. Either way it was agreed that much repetition over a considerable period of time, to consolidate the concepts involved, is necessary. Although teachers warn that the time that can be devoted to this topic is limited as it is only a small part of the primary curriculum.

One teacher said that since the widespread introduction of digital time, the teaching of analogue time has become harder, as children can often not see the need for analogue time when digital time appears easier. The teacher:pupil ratio was felt to be too small as children need individual attention with a subject like time, and much practical involvement. There should be increased opportunities for individual teaching, and frequent reference to time and much discussion between teacher and pupils and between pupils themselves. Poor resources at school, and lack of experience of clocks and time at home, were also blamed for problems. Teaching must be related to children's experience and children should be allowed to fully grasp one aspect of time before the next is introduced, to guard against confusion.

All these factors added to what is already a very difficult conceptual area, combine to make the task of teaching children about time very considerable indeed.

4.2.7.5.1 Errors

Few errors were mentioned and even fewer solutions were offered by teachers. This is probably because many of the errors children make in telling the time are likely to be difficult to detect within the normal classroom situation, without the use of specific diagnostic methods. Most teachers said they were interested in the diagnosis and correction of errors in telling time and would welcome help with this. But a few teachers believed that children simply guess when they don't know the time, without applying any particular method to obtain their answers. This study has shown this is very rarely the case.

The most frequently mentioned error was that of reversing the hands. Teachers usually attributed this to children *seeing* the hands incorrectly, but it was also suggested that children might confuse the *functions* of the hands. The cause would seem to be a combination of both these factors, as the former suggestion is supported by the fact that children often draw the hands in reverse, and the latter is supported by the children's frequent inability to give satisfactory explanations for the functions of the two hands, in this study.

Many of the suggested solutions for hand reversal, centre around the use of clocks with clear numbers and faces, and with clearly differentiated hands, colour coded and with emphasis on different lengths and widths. It was also suggested that children could be given coloured pencils to differentiate the hands when drawing clocks.

Problems with the position of the little hand were also said to be very common. Children often say the wrong hour in situations when the hour hand is between two hour numbers. Either the lower or the higher hour can be given, but once the hour hand is passed the half way point and approaches the next hour number, the likelihood of this is increased, for example 2:40 is read as 3:40. One teacher's remedy for this was the demonstration of how the hands move between one hour and the next.

For children taught to use "minutes to the hour" and "minutes past the hour", it was thought to be common to confuse the use of these conjunctions, particularly with reference to the quarter hour. Place value problems with digital time were also mentioned, for example writing 2:5 instead of 2:05. Some teachers reported that children read minutes as hours, for example, "20 to 3" is read as "8 to 3".

4.2.7.6 Advice Received And Required

No teacher had received any advice on how to teach time since qualifying. This was explained by the fact that advisers have very high workloads and therefore only visit if their presence is requested.

All teachers said they would like some advice, although a couple thought it would be difficult to improve on their methods as they already tried to exhaust all possibilities. Others said they were interested but would not necessarily have the time to look at, or act upon, written guidelines. One teacher specified that she would appreciate a structured approach that could be followed by all teachers, so that there would be continuity throughout the school years and one could be sure that children were recieving each step. However, she stressed flexibility of presentation, so that children who find one approach difficult could be given the opportunity to respond to another.

4.2.7.6 Recommendations For Increased Efficiency Of Teaching

Many teachers said they thought time should be taught later and in a more practical way, with more discussion around apparatus like sand clocks, for younger children, then conventional clocks, then timetables for calculations of duration at a more advanced level.

It was thought that as many different approaches as necessary should be used, so that if a child does not respond to one, he will have the opportunity to learn from another. One teacher specified better organisation, and measurement of progress levels so that if children are not doing as well as expected, they can be given additional teaching.

There is a definite call for more resources, both a wider range of resources and more of them. Teachers said they should encourage the use of children's own books and games brought in from home, which as well as increasing resources, would mean that the owners of these games could teach them to others. Ideas for practical activities with time would be welcomed, perhaps in the form of a project pack with posters and worksheets.

A need for improvement in teacher:pupil ratio, for smaller classes, more teachers and assistants, and more parental help, was expressed. The integrated day was viewed as beneficial as it frees teachers to spend a considerable amount of time with a single child if necessary. School 3 had a good system for encouraging parental help, each child had a "going home book" in which parents were given specific information about what the child was learning and where help was necessary. But it was stressed that the home environment can be damaging too, so parents must be given guidance on what type of help is required and how it should be given. This ensures continuity of approach.

All teachers said they would like some help with teaching time. Some were particularly interested in anything that might throw some light on an optimal way of teaching such a difficult subject. However it was stressed that any information for teachers should be presented in a clear and concise form since teachers are often pressurised for time. Courses were also suggested as being a helpful way of distributing information on the best teaching methods, as well as visits to see what is going on in other schools to give the teacher a wider perspective than the confines of her own classroom allow.

4.2.7.8 Conclusion

From talking to teachers it has been shown that teaching content and methods vary enormously, assessment is limited and informal, resources are poor and not used to their full capacity, and few errors are recognised as such and few avoidance or corrective techniques are practiced.

Thus the task of coming to understand and use the systems of time representation that we have evolved, is strewn with problems, not only at the level of the task itself, but at the level of school organisation, and that of classroom teaching environment as well.

There are many aspects of the situation that can be considered in an attempt to maximise the potential for learning. The rather limited literature that exists has attempted to address such questions.

CHAPTER 5: ISSUES RELATING TO CLASSROOM PRACTICE: A REVIEW

In what ways has developmental research influenced educational practice in respect of teaching time-telling skills? The most influential programme of research on the question of children's understanding of time is undoubtedly that of Piaget (eg., Piaget, 1946; Lovell and Slater, 1960).

There are two aspects of Piaget's approach that are worth stressing. First, he argues that - as in other areas of cognitive development - the relevant understandings are gradually constructed: the process of learning about time is a slow achievement in which incremental advances are built gradually upon one another to create ever more mature conceptions. Secondly, these achievments must be recognized as embedded in the general developments of operational thinking.

The impact of these principles has perhaps been to encourage a rather conservative attitude to what might be achieved in respect of the early acquisition of a metric for time. As in other areas of basic conceptual development (number, motion, mass etc.) a Piagetian perspective would discourage too hasty an approach to learning metrics until a mature grasp of the underlying concept had evolved.

This constructivist framework of developmental psychology may well have influenced practice in the most general sense of urging a cautious approach to teaching. This may be appropriate: children's engagement with time telling is likely to be motivated by the clarity of their grasp of the underlying concept. But interest within the present research is more focussed. At whatever level of operational development, the task of accessing a metric of time (for whatever clarity of purpose) is partly a task of processing the information represented in the conventions of clocks. It is the problem of teaching the "telling" of time that is of special interest here.

Unfortunately the literature to date is somewhat disappointing with regard to the information processing approach. Authors fail to present a clear, systematic picture of the processes involved in the development of ability to tell time. This is because the bulk of the literature comprises suggested methods of teaching time rather than an examination of how it is that children come to understand our system of measuring time.

The validity of the claims that proposed instructional programmes are effective is to some degree dependent upon the extent to which researchers have evaluated their programme. Unfortunately evaluation of the programmes themselves, and with respect to other approaches, is in most cases ignored. Most often researchers simply state that students progressed well on the described programme (eg. Bachrach, 1973). Few researchers back up decisions to pursue a certain line or use a particular variation in method with some solid evidence, it tends to be simply due to intuitive hunches. There is only limited attention to previous work, and in most cases no exact research methods are used.

Barcott (1973) acknowledged the problem that few attempts have been made to study the effectiveness of programmed time telling instruction. He developed a time telling programme, tested subjects both before and after exposure to it, and reported an increase in performance.

Only Nibbelink & Witzenberg (1981) specifically compared two methods under controlled situations. They measured subjects' time telling skills before and after exposure either to the traditional teaching method or to a method they devised themselves, and reported a greater increase in performance with the latter method.

Thus this work contributes little in the way of advancing knowledge concerning optimal teaching methods. This is great pity since there is enormous value in clarifying which teaching methods are most effective. With optimal approaches and resources, the task of the teacher will be much easier and children should learn faster and with better understanding. If this were achieved, the teaching of time telling would no longer be a source of extreme difficulty and, and instead would become an enjoyable learning experience.

However, it is worth considering the range and type of ideas proposed by researchers and teachers with an interest in this field.

5.1 THE APPROACH

All researchers acknowledge the difficulty of learning to tell time and therefore of teaching children to do so, but they point out that fortunately motivation is on our side. In fact motivation is one of the major factors thought to account for the almost universal acquisition of satisfactory time concepts among ordinary children. It is of even greater relevance to children with special needs, as they must expend more effort than ordinary children to complete the required tasks.

Children's experiences with clocks at home, are said to help set the background for learning to tell time. At a young age they learn to identify a clock and have a vague notion that it is something quite important. They want to understand their environment and emulate adults. For this reason parents are often very influential in motivating their children to learn to tell the time, both generally through teaching and encouraging development of the skill at home, and more specifically by the promise of a watch or a clock as a reward for mastering the skill. There is a tendency to purchase it prematurely, but this is not necessarily a bad thing as the fact of possession is in itself a powerful motivational factor (Nibbelink & Witzenberg, 1981).

For these reasons telling the time is agreed to be a most enjoyable and rewarding topic to teach, in spite of the difficulties encountered However, if children are to progress beyond regarding clocks as interesting toys, it is stressed that they must receive highly structured and sequential tuition.

5.2 STARTING POINT

When we should begin to teach time is a debated issue in the literature. It is pointed out that where clock reading should appear in the curriculum is unclear from the textbooks. The National Curriculum emphasises that teaching time should start at an early age although it is not assessed for some time. So although the topic of time is not specified at Level 1, it is essential that much preparatory work occurs to help children know the language of time by

Level 2, and to read clocks by level 3. If this is to be achieved, then some drastic changes will have to occur in teaching approach.

Benoit & Valeno (1962), believe that awareness of time and interest in clocks should be encouraged even before children are willing to work with clocks. Springer (1951) demonstrated that pre-school children have considerable knowledge of the clock even before time telling instruction has begun.

Maertens (1980) states that teachers, recognising how important time is in our culture, tend to begin teaching children about time as soon as they enter school, but he questions whether this is necessarily a good thing. Lumb & Papendick (1978), on the other hand, suggest the use of a clock as soon as children express interest.

Some researchers believe that not until the concept of time, as defined by Piaget, is fully developed should time telling instruction begin (eg. Riley, 1980), others suggest that it is quite reasonable to teach the skill early and allow a deeper understanding to develop with time Clearly until some insight into the relationship between the concept of time and the telling of time has been gained, we cannot be sure of how much understanding of one is required for the other and therefore exactly when they should be taught in relation to each other.

Benoit & Valeno (1962) suggest beginning time telling instruction when children are ready to learn to discriminate between numbers and digits. They do not believe that mental age is a good predictor of readiness to learn to tell the time since there is a large variation in skill development, nor do they support the use of IQ measures to determine readiness. Instead they consider the child's consciousness of time to be the important factor. Nibbelink & Witzenberg (1981) suggest teaching clock reading in grade 2, and from various pilot studies they concluded that grade 1 was too early.

Thus it can be seen that researchers are unable to converge on the issue of when time telling should begin.

5.2.1 Pre-requisites

A decision as to when to begin time telling instruction must necessarily include some consideration of the required prerequisite skills both of the skill itself and of the chosen method of instruction as well as a clear idea of the developmental stage of the pupils concerned.

From an examination of the skills required to learn to tell the time sucessfully, the necessary prerequisite skills can be exposed. There is some difference of opinion, but the majority of researchers agree that the main prerequisite to being taught to tell the time using an hour hand, is the ability to recognise and identify the numbers 1-12 (eg. Lipstreu & Johnson, 1988), and that teaching telling time using the minute hand presupposes an understanding of numbers which will enable a child to count to 60 by both ones and fives. (eg. Krustchinsky & Larner, 1988). Britton (1981) stresses that if a child does not understand these number relationships, the teacher should go back and teach him them before proceeding with instruction in telling time.

Partington et al (1979) completed a task analysis to determine only those skills essential to time telling, for use with mentally impaired children. They concluded that the minimum prerequisite skills required to learn to tell time to the minute are the ability to identify the numbers 1 to 12, count from 1 to 30, and discriminate between the two hands of the clock.

Peterson (1983) stresses that if the children are to learn the fractional terms of the clock, it is essential that they understand the idea of one-half and one-quarter, and are taught to generalise these to the clock.

There is also some debate as to when the skills involved in time are reasonably well developed. The consensus of opinion is that children are capable of telling the time fairly well by the age of seven (eg. Ames, 1946). However, some reasearchers conclude that even younger children are adept at telling time, for example Schecter, Symonds, and Bernstein (1955) conclude that six year olds are good time readers. On the other hand, some workers see the skills as much later developing, McIntyre (1975), for example, believes that a mature concept of time is not acquired until 8 or 9 years and that before this, telling time is only dial reading.

5.3 PROPOSED METHODS OF TEACHING

5.3.1 The Concept Of Time And Telling Time

There seems to be a complex relationship between the concept of time and telling the time. However researchers emphasise that acquiring time concepts and the development of the ability to tell time do not necessarily go hand in hand. Although children may be able to associate clock positions with certain events and may be able to read a digital (or even an analogue) clock, this does not ensure that they fully grasp the concept of time (eg. Horak & Horak, 1983). It is generally agreed that a good educational program must teach children about the passage of time as they learn to read clocks, so that the ability to tell time and a concept of time, develop together (eg. Thompson & Van de Walle, 1981). However researchers tend to look at either the concept of time or telling time and few consider the two aspects together. The work of those who have concentrated on outlining an instructional sequence for reading time, is reviewed here.

5.3.2 Approach

One of the most common features of intructional programmes is that the clock is usually split up into its constituent hour and minute parts for teaching purposes. This is particularly true for programmes designed for use with learning disabled children because researchers believe such children find it difficult to cope with two hands and two metrics at once (eg. Britton, 1981). The advantage of this approach is that it allows children to focus on each aspect of telling time separately (eg. Horak & Horak). Strangman (1972) believes this will prevent later confusions. Krustchinsky & Larner (1988) suggest teaching the hands separately because learning disabled students often have visual- perception difficulties.

Some researchers begin with a clock face without hands, since the lengths of the hands and what they are pointing to are thought to be confusing. One such method was proposed by Krustchinsky & Larner, who had children practice counting minutes by ones and fives until they were quite accomplished.

Some researchers construct "minute-face" clocks and/or "hour-face" clocks. A "minute-face" clock has minute marks, numbers and hand only, whereas an "hour-face" clock has hour marks, numbers and hand only. The "minute face" clock can vary depending on the amount of marks and numbers present on the clock.

Two handed clocks which may or may not have numbers on them, are also used. These can be of the conventional type or can incorporate the addition of all or some minute numbers, or the removal of hour numbers. Sometimes two hands are present on a clock, but the minute hand is kept stationary at 12, 6, 3 or 9.

The exact sequence of presentation of parts of the clock varies considerably between suggested programmes of tutition. An example of the range is presented below.

When one hand alone is used to begin instruction, the hour hand is normally chosen, since the precision given by the minute hand is considered by many researchers to be unnecessary in initial instruction. In a number of programmes, the hour hand is preceded by the use of a sundial and comparisons between the two are made (eg. Thompson & Van de Walle, 1981). Later the minute hand may be added or may be presented on its own before the two are used together.

It is common in cases where the hour hand is presented alone, to use approximate language to describe time in the initial stages of teaching time, for example, "about 6 o'clock", "a little after 2 o'clock", "a little before 3 o'clock", "about half way between 4 and 5 o'clock".

Krustchinsky & Larner (1988) first used a clock face without hands. Then they introduced the minute hand and after practice using this, they reported that children could tell time when the hour hand was introduced.

Thompson & Van de Walle use a sundial, then an "hour-face" clock, "minute-face" clock, two hands on a clock with minute numbers, then an ordinary clock.

Horak & Horak (1983) use a progression of homemade slit clocks, each a little more detailed. They start by using "hour-face" clocks, and discuss approximate time. Then, to highlight the fractional parts of the hour, before telling time to the minute, they use a "minute-face" clock without numerals, then add minute numbers in fives from 5-55. Lastly they use a two handed geared clock.

Nibbelink & Witzenberg (1981) recommend the use of the hour hand only, then both hands and a series of clockface rims, so that at first all the minutes are numbered, then only the five minute marks, then only the fifteen minute marks, and finally a normal clock is used.

However, there is a potential danger which is not acknowledged by researchers, of presenting transitional clocks that are sufficiently removed from reality as to be unrecognisable to children, thus defeating the object of simplification. This may be one of the reasons why Lipstreu & Johnson (1988), in contrast to most other workers, developed the "Whole Clock Method" of teaching children to tell time. This shows the clock as a whole and presents time in a natural, sequential manner. Times are not taught in isolation, instead children learn that every hour has the same five minute intervals. All o'clocks are learned, then all 5 minute pasts are learned with a review of the o'clocks, then all the 10 minute pasts with a review of the o'clocks and five pasts, and so on. Lipstreu & Johson believe their method facilitates generalisation and highlights the continuity of time.

Reisman (1971) also does not present the hands separately. Since the coordination of the movement of the 2 hands must be understood, she sought to find an instructional method which included a strategy for decoding the position of the hands which involves recreating the paths of the hands from the starting point at 12. She proposes teaching time to the minute, because telling the time is based on counting and children learn to count by ones first. By analysing the skill of reading time to the minute, she developed a programme of instruction which she claimed enabled even first graders to tell time to the minute.

5.3.3 Steps

All researchers seem to agree that there should be an instructional programme involving a series of steps, each of which has to be mastered before the next is taught. They stress that the sequence should be flexible so that children are able to progress at their own speed which is particularly important for those with special needs (eg. Benoit & Valeno).

5.3.3.1 Possible Sequences

The traditional sequence is generally agreed to be a fractional approach, which teaches time on the o'clock, half past, quarter past, quarter to, five minute, and one minute points.

There are two alternative sequences of instruction, these are the "past/to" method in which time is taught as "minutes past" the hour up until the thirty minute point and "minutes to" the hour from the thirty minute point until the following hour. Hofmeister & LeFevre contrast this method with the alternative method in which minutes are counted as past the hour all the way around the clock to 60. There is also a "digital" method in which times are read in hour:minute form.

3.3.2 Criticisms

Recently the traditional sequence of instruction has been called into question by researchers. Nibbelink & Witzenberg (1981) compare subjects' performance on the traditional method with that on a method they devised themselves. Their method assumes that reading a clock involves memorizing numbers for positions rather than counting by fives and counting beyond multiples of five. They conclude that the traditional approach to teaching time is less effective than their own method.

There are a number of diverse theories put forward to explain the inadequacies of the traditional method. Thompson & Van de Walle (1981) point out that with traditional instruction good concepts of duration are not always developed and minute numbers are not usually present on clocks which means extra mental computation is required to calculate them. Reisman (1971) complains that traditional teaching methods treat the clock as a static relative of the calendar rather than a dynamic counter and fail to properly emphasise the relationship between the movement of the two hands. Lipstreu & Johnson 1988) criticise the traditional method for incorporating no sequential learning around the clock and being based on the idea that students should learn to group times together.

Reisman and Kaufman (1980) argue that the traditional sequence of introducing hours first, then halves, quarters and units of five minutes, presents the more difficult parts of the task too early. Children may become fixated on the hour and half hour, making telling time to the minute more difficult. Teaching time to the minute does not occur until the last step of the traditional sequence (usually in grade 2 or 3), and fractions of the hour are introduced before the concept of minutes past. The natural mathematical development is to learn to count by ones first, so they assert that children should be taught time to the minute first, since children learn to count by ones first not last. Thus they conclude that the traditional sequence of instruction has been backwards.

Thompson & Van De Walle (1981) criticise the traditional instructional sequence, which teaches fractional terms followed by "minutes past" and "minutes to", for requiring new concepts to be learned at each new level, since an understanding of say quarter past is no help in mastering the concept of minutes to.

The "past/to" method is criticised on a number of counts, for example Thompson & Van de Walle believe that many children confuse the application of "minutes past" and "minutes to", and Lipstreu & Johnson point out that it is not easily transferred to digital time. The "minutes past" method seems to be the most popular amongst researchers.

5.3.3.3 Sequences Of Instruction Used

Sequences used vary widely. An example of the range in the literature is given below.

Hofmeister & LeFevre (1977) teach the "minutes past" method. They divide the process of instruction into 8 sequential tasks, these are, the recognition of the numerals 1-12 and their positions, reading the hour hand when no minute hand is present, discrimination between hour and minute hands, reading time with minute hand constant, counting by fives with only the minute hand present, discrimination between reading hour and minute hands when only one hand presented at a time, reading time to five minute intervals, and reading time to one minute intervals.

Bachrach (1973) suggested five phases of tuition for slow learning pupils, beginning with the hour hand only using approximate language, then o'clocks, half hours, counting by fives using the minute hand only, then all times on a conventional clock.

Maertens (1980) teaches according to the traditional method. Partington et al (1979) designed a sequenced time telling programme in which time was taught on the hour, before and after the hour, minutes before and after the hour in five minute intervals, and the half hours. Nelson (1982) also presented fractional terms after minutes. He began with time to the hour, then time was read to the minute prior to being read to the half hour or to the quarter hour.

Britton (1981) proposes a series of steps involving the drawing of clocks, and manipulation of alarm clocks to show the movement of hands from hour to hour and their correspondence to a period of time. First the child draws a clock freehand, then the pupil is taught to draw a clock with five minute points marked correctly by copying increasingly detailed drawings. By manipulation of the hands of a real clock, he learns to set one o'clock, then 1:05, 1:10 etc. This procedure continues until the child is able to tell time to the fives minute point. Then the same procedure is followed for time on the one minute point. Lipstreu & Johnson (1988) present a similar sequence, they teach all the o'clocks, all 5 mins past with review of o'clocks, all

10 pasts with review of 5 pasts and o'clocks, etc.

Children can either be taught to tell time to the five minute point, and then to the one minute point, or vice versa. Hofmeister & Lefevre, Bachrach, and Britton, have been shown to teach time to the five minute point, but some researchers do not agree with this approach. Krustchinsky & Larner (1988) taught children to count minutes past in ones at first and then encouraged them to "count the quick way", by fives by counting the darker marks. Reisman (1871) also teaches time to the one minute point first. Maertens (1980) warns that we should not attempt to teach children the shortcut of counting each numeral as five minutes, as this will come later as they gain confidence and experience. Lumb and Papendick (1978) suggest that once a firm knowledge of the minute as a unit of time has been acquired, the minute marks can be counted in fives, but warns that minutes to the hour are more difficult and should be taught later.

5.3.4 Time Variations

Instructional sequences are also effected by variation in expression of time. Possible methods of expressing time are fractional terms, "minutes past", "minutes to", and digital reference, or combinations of the first three methods.

The traditional variation of expressing time in terms of fractional parts of the clock, at first sight, from an adult's point of view, may seem to simplify the matter of reading time, but to young children who have little or no concept of fractions, it may cause unneccesary confusion.

The combined use of "minutes past" and "minutes to" is thought to lead to confusion between the use of "past" and "to". The "minutes past" method seems less confusing, and it has the added advantage of being more compatible with digital time. The only disadvantage with this method is that time does not tend to be expressed in this way in the real world, for example "51 minutes past 6" would tend to be reported in terms of "minutes to" the hour, or digitally. Proponents of this method do not see this as an unsurmountable problem, but merely a cosmetic detail which can be ironed out after the main skills of telling time have been mastered. Digital reference to time has the advantage of being compatible with both digital and analogue representations of time, but unlike the other variations of expression, requires the hour to be said before the minutes, so is not the preferred method for reading the analogue clock.

Many researchers believe that only one variation of saying time, should be taught at first and completely grasped before further variations are introduced, to avoid confusion. Instruction should advance slowly until each variation is learned completely (eg. Lipstreu & Johnson, 1988; Bachrach,1973).

Some researchers specify the use of time variations in certain sequences. Strangman (1972) first teaches the digital variation then uses fractional terms. Maertens (1980) begins with fractional terms and then uses "minutes past". Thompson & Van de Walle (1981) suggest teaching children to read time as minutes past then introducing terms like quarter past at a later stage. They assert that fractional terms must still be taught to children at some point since they are in widespread use.

Peterson (1973) believes that much of the difficulty in telling time can be accounted for by the profusion of terms used to state the time in oral and written form. He says the problem can be reduced by limiting the terminology to "minutes after" the hour in the beginning. Thompson & Van de Walle agree, they found that teaching time initially as minutes after the hour provides a conceptual framework into which all of the other usual clock technology can be fit.

Other researchers use two or a three types of terminology interchangeably from the beginning of the instructional sequence. DeLoach began with fractional and digital terminology at the same time. Krustchinsky & Larner (1988) and Benoit & Valeno (1962) use both the digital format and minutes after the hour together.

5.3.5 Relationship Between The Two Hands

An understanding, however implicit, of the relationship between the movement of the two hands is stated by many researchers as a crucial factor in learning to tell the time. For this reason the movement of the minute hand in relation to that of the hour hand is often emphasised during instruction (eg. Thompson & Van De Walle,1981).

The teacher can simply explain and demonstrate that every time the hour hand moves from one numeral to the next (one hour), the minute hand makes one complete revolution of the clock face (60 minutes) (eg. Riley, 1980; Krustchinsky & Larner). Similarly Maertens (1980) proposes that the teacher shows children how the minute hand travels halfway around the clock while the hour hand moves to the midway position between two hours. He suggests that the children are helped to count the intervals to show that the minute hand has moved 30 spaces.

Old geared analogue clocks are said to be a a useful resource to reinforce this concept, as they enable children, through manipulation of the hands, to recognise the relationship between the movement of the two hands, which is often hidden by the slow movement of working clocks (eg. Britton). Horak & Horak state that a worthwhile activity on ungeared clocks is for children to recognise and demonstrate impossible combinations of hand positions. Lipstreu & Johnson suggest that through a progression of times students are able to watch the hand movements and make there own inferences about how a clock operates.

Thompson & Van De Walle suggest questions to facilitate this understanding, for example, "Where is the minute hand when the hour hand points directly at an hour number? " and "Let's watch what the long hand does as the hour hand goes from 2:00 to 3:00".

5.4 RESOURCES

Researchers have suggested a variety of resources for teaching telling the time. These include sundials, geared and ungeared real clocks, homemade clocks with a variety of hands, marks and numerals. Flexibility of resources is stressed. When learning about time children should have access to a variety of clocks and watches, both analogue and digital, of many sizes and shapes (eg. Nibbelink & Witzenberg, 1981).

The issue of what type and combination of clocks to use, is tackled in a number of ways. A small minority of researchers, such as Lipstreu & Johnson (1988), use only real clocks for instruction. Many workers have developed instructional programmes designed to be taught solely with homemade clocks. For example, Nibbelink & Witzenberg proposed the use of homemade clocks with a series of rims containing a decreasing amount of minute numbers. Horak & Horak used a series of slit clocks made from paper plates. DeLoach used simple homemade clock faces because she considered real clocks to have too much information on them.

Some programmes are designed for use with a combination of real and homemade clocks.

Irrespective of the types of clocks used for their instructional programme, almost all researchers do recommend the availability of a variety of clocks and watches, both analogue and digital, in the teaching environment. They emphasise that children need to learn from the experience of manipulating real clocks, both geared and ungeared (eg. Lipstreu & Johnson, Britton, Nibbelink & Witzenberg). The advantage of geared clocks is that children are able to learn about the relationship between the two hands, this is vital even though children may not actually be able to articulate it. Ungeared clocks also aid this understanding as they allow children to discover impossible combinations of hand positions.

5.4.1 Homemade Clocks

Homemade clocks are very popular, probably because they allow for the manipulation of the traditional clockface to fit individual teaching and learning styles. Riley (1980) conducted his research with a transitional clock since he believed the ordinary clock to be too confusing. A large variety of homemade clocks have been proposed in which the number of hands and the extent of the numbering are changed. Benoit & Valeno (1962) believe toy and educational aids to be inadequate, and assert that fastest progress is made with a homemade clock which can accommodate various dials, corresponding to the various stages of learning to tell the time.

5.4.1.1 Arced Clocks

The apparent difficulty that children experience when reading the hour hand has led to the development of clocks that have some mark to aid children in reading the hour correctly. But proponents of these clocks, with the exception of Peterson (1973), do not acknowledge the possibility of encouraging further confusion.

Riley proposed a transitional teaching clock on which the hours are marked by arcs to indicate when time is in each hour. Similarly Lumb & Papendick suggest dividing the hour band into intervals of half an hour on either side of the hour mark can aid children in determining which hour to read.

Peterson proposes the use of a "half-hour" clock to begin instruction of the half hour. This has an adjustable hour hand and a minute hand which is stationary at the six. Hash marks are spaced half-way between each pair of hour numerals. These are used to assist the children in accurately placing the hour hand exactly halfway between two numerals when setting the clock on the half hour. Similary he proposes the use of a "quarter-hour" clock, for which the minute hand is fixed at the three and hash marks are placed one-quarter of the distance between each pair of hour numerals. He warns that the hash marks will appear to some youngsters as before the hour on the left-hand face of the clock.

5.4.1.2 Linear Clock

Schultz (1979) designed the linear clock as a temporary device to aid transition from intuitive to clock time. Since displaying time as distance is consistent with childrens' ideas of time as detailed by Piaget. An indicator moves uniformly along a number line, marked initially with hour numbers, but later it can be more detailed.

5.4.1.3 Self-Checking Clocks

Horak & Horak (1983) propose the use of self-checking clocks which have hour hand and numbers on the front and on the back, a minute hand

and numbers in a counterclockwise direction by 5s from 5-55. They suggest children use these alone or in pairs to help them associate minute numbers with their locations on the clock face, so that they can tell time when the minute numbers are no longer present.

Thompson & Van de Walle (1981) specify self-checking flash cards on the front of which is an hour clock. The child must set the position of the minute hand on a paper plate clock and can check his answers on the reverse of the card.

5.4.1.4 Minute Numbered Clocks

Krustchinsky & Larner (1988) state that at first it is important to use clocks with minutes indicated clearly on the outside edge, since on an ordinary clock face the numbers refer to hours, not minutes and this is confusing. Once the children are confident, the variance in clock designs does not matter. Thompson & Van de Walle point out that the presence of the minute numbers on the clock eliminates extra mental calculating that must be completed with regular clocks. They used a minute hand clock showing the 60 minutes, with 5 minute intervals numbered, and gradually decreased the amount of minute numbers available.

Riley's transitional clock had minutes numbers in addition to hours numbers. Lumb and Papendick (1978) use clocks with numerals 1-12 on an inner band of the clock and minute marks on an outer band of the face. Nibbelink & Witzenberg (1981) developed snap on rims with varying amounts of minute numbers, for use with the same basic clock.

5.4.1.5 Sundial

Thompson & Van de Walle suggest using a homemade sundial as an introduction to telling time and using clocks because it shows the passage of time looks similar to a clock face, especially when numerals are written to correspond to shadows at various times.

5.4.2 Number Lines

A minority of researchers liken the analogue clock to a circular number line, since a number line is usually familiar to young children (eg. Krustchinsky & Larner). It is thought that the use of the number lines of 12 and 60 can aid children in understanding numbers on the clock face.

Reisman (1971) suggests beginning instruction using a number line to count from 0-60. She developed a clockface and a plastic snap-on simulated number line from 1-60. Experience in counting from 1-60 on the number line was generalised to the minute marks on the clockface. One-to-one correspondence is apparent as each number is matched to a minute mark. Then a number line from 0-12 was attached to the 60 number line, so that the numeral 1 on the former corresponded to 5 on the latter. This exposed the underlying multiplication relationships that one group of five is five, etc. The active involvement of the child was thought to aid learning.

Krustchinsky & Larner (1988) used the 60 number line and related this to the clockface but did not corrupt the clock itself by placing extra numbers on it.

Peterson (1973) also proposes that instruction should start with a number line. Children should practice which number comes before and after a given number. Once the children have mastered the linear number line, the numbers should be placed around a circle used to represent a clock, and the same procedure should be followed. Next, an unnumbered clock with the intervals of five minutes indicated by marks should be presented and children should practice locating the position indicating each five minute point. As the children gain confidence, the minute and the hour hand should be added.

5.4.3 Colour Coding

Another cue which is often helpful to children is colour coding. For this reason it is often incorporated into homemade clocks. The minute marks, numerals and hand are made in one colour and the hour marks, numerals and hand are made in a contrasting colour. This is the case for "minute-face" and "hour-face" clocks (eg. Horak & Horak, 1983), as it allows for easy differentiation between them, as well as clocks with both hands or numerals (eg. Riley, 1980).

Instructors should be consistent so that all clocks used are coded in this way, including the teacher's demonstration clock (eg. Thompson & Van de Walle). Jeffers (1979) recommends the use of a digital clock in conjunction with an analogue one, and suggests applying the same colour coding to both clocks so that children are able to see the relationship between the two representational systems.

5.5 ERRORS

Few researchers mention the occurrence of errors, and even less were found to attempt a classification of error types.

5.5.1 Classification Of Error Types

Lipstreu & Johnson (1988) describe the 3 most common errors with any instructional method as mixed hand, wrong minute, and wrong hour. They believe the first is an early error due to difficulty in distinguishing between the two hands. The second is due to counting minutes incorrectly and can be remedied by the student counting round the clockface by fives to the minute hand. The third error occurs as the hour hand approaches the next hour and is usually the last to be overcome. Lipstreu & Johnson see this error as one of the most challenging to correct since the appearance of the time can be deceptive. They claim that a "progression" of times is one of the most effective corrective techniques. They believe the child should be given the opportunity to make his own inferences about the movement of the hands by providing a "progression" of times. For example if a student makes an error on 8:50, he would then have to identify 8:15, 8:20 etc until he reached 8:50. Generalisation is emphasised as a correction technique for all three types of error since learning is naturally integrated, eg. if a student fails to correctly identify 3:10, he is told the correct time and then given practice on all other 10 past times.

Reisman (1971) also believes in recreating the movement of the hands from their starting point at 12. She suggests a more detailed sequence of errors... 1) reversal, a) between minute and hour hands, b) between quarter past and quarter to the hour, 2) future hour named, 3) previous hour named, 4) wrong minute. Her explanation is that errors 2 & 3 reflect a lack of awareness of synchronised hand movements due to focussing on the static appearance of the clockface. Errors 1a & 1b may be perceptual, due to a misunderstanding of the movement of the short hand as related to that of the long hand, and so states that this relationship must be emphasised to the child during instruction. Error 4 may be due to the traditional teaching sequence of hour,quarter, 5 min, 1 min.

Springer (1952) looked specifically at the degree of understanding reflected in wrong answers as she believed this to be a necessary route for formulating a program of instruction in telling time. She found that the same types of errors occur with about the same frequency in telling and setting time, so combined the data for the two tasks. Percentages for six year olds were... minutes incorrect (44%), hour identified with long hand (29%), counting incorrectly (5%), identification by angle of hands (3%), other, including guesses (19%).

5.5.2 Errors Mentioned

5.5.2.1 Wrong Hour

Only hour mistakes and reversals of hands were reported by other researchers. When the hour is stated incorrectly, it is often the hour adjacent to the correct one that is chosen, particularly in cases after 30 minutes past the hour, where the hour hand is actually nearer to the next hour than the present one (eg. Peterson, 1973). This problem is confounded when, usually at a later stage, "minutes to the hour" is introduced. Researchers emphasised that it is important to warn children of these confusions and have effective methods of correction.

Verbal Cues were commonly used to remind students that there is something to be wary of. Horak & Horak (1983) give initial emphasis on "before the hour" times and "after the hour" times and children are told that the minutes after numbers are not the numbers used for before the hour times. Krustchinsky & Larner (1988) explain that when the hour hand is between two numbers it belongs to the lower number.

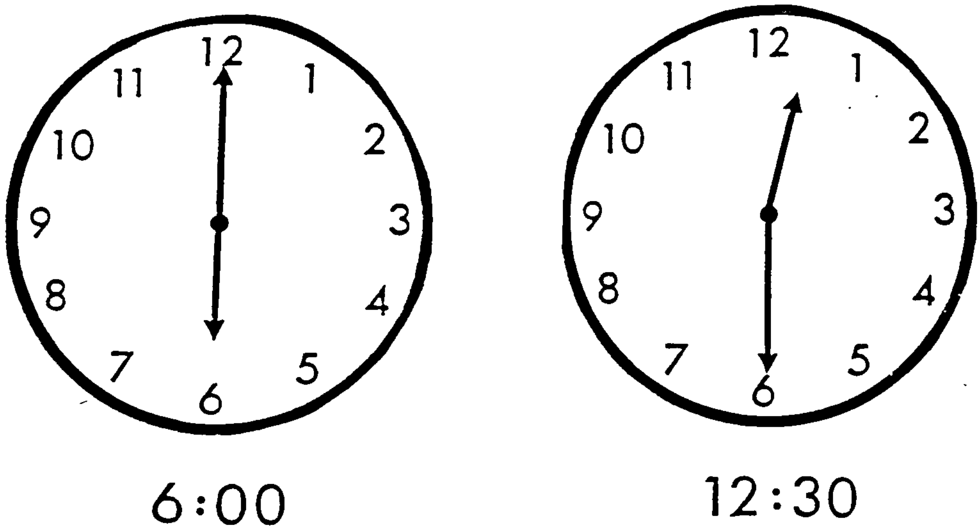
Hofmeister & LeFevre suggest that the student should count the numbers round the clock and say the last number before the hour hand. Riley proposes a transitional clock on which the hours are marked by arcs to indicate which hour time is in.

5.5.2.2 Reversed Hands

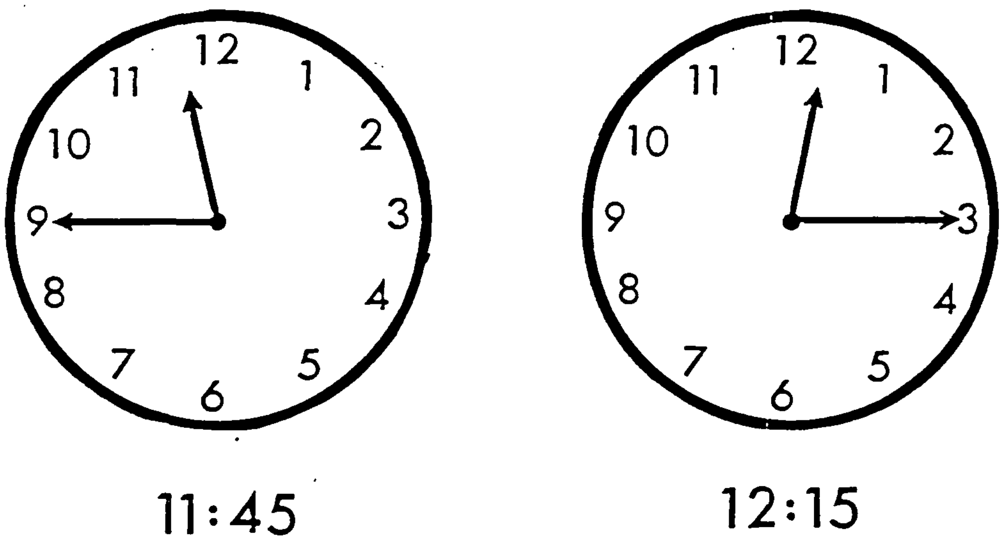
It is reported that a major source of confusion is the differentiation of the two hands, both in physical appearance and in function. To avoid difficulties later, it is suggested that care is taken to draw children's attention to the differences between the hands. Krustchinsky & Larner explain that the clock has two circles of numbers, an outer one indicating minutes and an inner one indicating hours. The minute hand must be long to reach the outer circle whereas the hour hand can be shorter. Lipstreu & Johnson (1988) use verbal cues, such as "big hand", and "little hand". Bachrach (1973) emphasises that the short hand *points* to a numeral whereas the long hand *covers* a numeral. Horak & Horak suggest the construction of "minute-face" and "hour-face" clocks which are coded in different colours so that the children can easily differentiate between the two. Bachrach tells children to write the time digitally and enlarge the two digits to the right of the colon to reinforce the idea that the larger hand is represented by the larger figures to the right of the colon and the short hand by the smaller figures to left of the colon.

Peterson (1973) makes clear the confusion that can occur in distinguishing between time on the hour and time half past the hour solely through errors of visual perception (figure 5.1). He points out that there are only two ways to distinguish between such times as 6 o'clock and 12:30, using visual-perception skills. Either children must observe that the big and little hands are in opposite positions or they must see that the hour hand does not point exactly to the hour but slightly beyond it.

Peterson pointed out that the widespread difficulty of the development of the fundamental visual-perceptual skill of laterality, especially amongst mentally retarded children, is bound to lead to considerable confusion in attempting to read time on an analogue clock, such as those times shown on figure 5.2.



5.1 Hour and Half Hour Confusions



5.2 Laterality Confusions

These are subtle discriminations which must not be taken for granted. Many children have difficulty in differentiating the reversed positions of the hands and are not able to detect the difference of a hand pointing exactly at a numeral and a hand pointing between two numerals. For children who appear to experience difficulty, he suggests the use of initial perceptual training exercises.

5.6 DIGITAL AND ANALOGUE TIME

With the recent introduction of the digital representation of time and its increasing pervasion in our society, the problem of how to integrate its use and teaching with that of the analogue timepiece can no longer be overlooked. Reseachers have attempted, in a variety of ways to accommodate it, and most agree that both representations of time must be taught.

Riley (1980) believes that the analogue clock, with moving hands is a better alternative for teaching than the digital clock, since children relate time with movement (Piaget). Nibbelink & Witzenberg (1981) agree that the time-distance feature of the movement of the hands of the analogue clock is psychologically significant, and this may be why adults tend to prefer it. Riley points out that users of analogue timepieces add and subtract time geometrically whereas a digital watch requires an arithmetical operation. However he does wonder if time telling and its teaching would be easier with only a digital representation of time.

Schultz (1979) supports the use of analogue clocks since they provide a perceptual, qualitative idea of time intervals, and although precise calculation is more difficult than with a digital timepiece, estimation is sufficient. He states that digital clocks simplify reading time to simply reading numerals but make the calculation of time intervals more difficult since they require addition and subtraction around 60. In fact he believes that in time digital clocks will supplant analogue ones and so questions whether by teaching the reading of analogue clocks we are teaching an obsolete skill.

Britton (1981) points out that children with learning difficulties who fail to grasp analogue clock time even though they may learn to read a digital clock, often never really seem to understand time concepts. From this he infers that digital time may not be a sufficient tool for the sucessful acquisition of a full understanding of time.

Workers such as Horak & Horak (1983) and Jeffers (1979) who believe that the reading of digital time precedes both the ability to read analogue time and the development of the concept of time, agree that the ability to read a digital clock does not always imply an understanding of the passage of time, and so conclude that the teaching of time-telling is not complete without the use of digital clocks. For this reason Jeffers suggests we use the digital clock in conjunction with the analogue clock.

5.7 CONCLUSION

From the literature it can be seen that views on when to begin teaching, what to teach, and how to teach it, differ widely. Issues considered include whether the clock should be presented as a whole or in parts, the sequence of instruction, and which variations of expressing time should be encouraged. In addition, how much concept of time is necessary before time telling instruction begins, and when analogue and digital time should be introduced with respect to each other, are also considered.

Thus a large number of inventive and interesting ideas emerge. However, there is little to differentiate between them, since decisions to pursue a certain approach are rarely justified and evaluation of the effect of proposed teaching methods is virtually non-existent.

What is needed is attention to previous work, more careful research methods, and an emphasis on proving the benefit of a particular variation in method.

More importantly, there should be a shift in perspective towards an attempt to illuminate how children come to understand our system of time measurement, and the difficulties they experience, so that the development of optimal teaching approaches can be based upon a solid foundation of knowledge.

CHAPTER 6: CONCLUSION

6.1 Conclusions From This Study

6.1.1 Test Performance

An account has been presented of how young children of different ages respond when asked to read and set digital and analogue time. Moreover, the particular difficulties young children seem to encounter in respect of these tasks and the features of our representational systems of time that are conceptually difficult for children to decode, have been exposed. From this, something of the nature of the development of the ability to tell time has been inferred.

At first glance, the skills required to read time, especially digital time, may seem uncomplicated. However, the performance of subjects on the test has shown that time telling is more difficult for children than has previously been supposed.

Children are much worse at telling time than expected. Only 25% and 5% of second year junior children performed without error on digital reading and analogue reading tasks, respectively. This indicates that the development of the skills involved in successful completion of these tasks, continues well beyond the age group considered in this study.

Children performed better on reading than setting tasks. The dependence of setting response on that of reading, makes inference of developmental sequence of these two skills difficult. Similarly, whether children's better performance on setting analogue time than digital time, is a reflection of greater understanding of analogue time, is unclear.

It is clear, however, that children find it easier to read digital time than analogue time. Overall scores for reading digital time were higher than those for reading analogue time. This does not necessarily mean the skills of digital time are more developed, it may be a reflection of the easier nature of the digital reading task. There is a potential danger that the fluency of children when reading digital time may mislead educators into believing that they have a well distributed understanding of the operation of the digital clock, which is often not the case.

Development of the ability to read and set time is a gradual process which occurs over a number of years. Children get better at telling time as they get older. School was also found to affect performance. An enormous numbers of factors differ between schools which could contribute to this, including teaching methods, classroom and home environments. Children are better at reading times on the o'clock than those on the minute points, in both digital and analogue representations. Additionally they are better at reading times on the five minute point than those on the one minute point when reading analogue time.

Children exhibited a large number of errors and analysis of these showed that they are not simply wild guesses but are driven by certain rule systems, albeit incorrect. The importance of developing a theory to cope with with cognitive demands of novel tasks is stressed by Karmiloff-Smith & Inhelder (1975).

Thus children are approaching these tasks in a reasonable fashion and making valid attempts to make sense of them as best they can. In spite of the fact that children *are* using rules, and there *is* method in their approach, a large number of mistakes still occur because of the complicated nature of the task, and the numerous potential sites of confusion of which the stimuli are comprised.

The preliminary taxonomy of possible error types constructed, exposes the vast extent of the misunderstandings that can occur when immature time readers attempt to decode analogue and digital clocks. This should at least put educators on their guard to watch out for their occurrence and to view incorrect time telling responses by children as intelligent approximations to reality rather than uneducated guesses.

6.1.2 Explanations For Test Performance

Reasons offerred for the low performance levels of subjects include the extreme difficulty of the task itself, poor organisation at the school and class levels, and limited resources.

The task of reading analogue time is difficult because children must read two metrics from one dial, map minute and hour numbers on to the correct hands, co-ordinate the movement of the two hands and recognise the relationship between them, and correctly identify the numbers either by counting or by memory.

Reading digital time is a simpler task but confusions are still widespread because children must realise that there are two sides to the clock and that one indicates minutes and the other hours, then they must correctly integrate these two parts. Lastly the numbers must be read correctly.

School organisation of mathematics teaching, especially that of time, is casual, so that teachers are largely left to decide on their own teaching methods and content. Thus there are huge differences in what is taught and how and when it is taught within individual classrooms.

The classroom as a learning environment for time telling is far from ideal. Children had very little opportunity to relate spoken time and events to symbolic time as represented on a clock face, since in all but two of the classes visited, there was no working class clock, and one school did not allow the wearing of watches.

Under these circumstances, it is unreasonable to expect young children, who spend all day in the classroom, to have a well developed sense of time. There must be a clear clock, of at least one representation, on the wall, at an appropriate level for the child to see.

All other classroom resources were also found to be deficient. Although all classes visited had some access to a computer, only four teachers used this as a resource for the teaching of time. Thus the computer is at present not being used to its full capacity. This is largely because software provision in schools is very limited, and what does exist, is poorly publicised. Mathematics schemes are not ideal bases for teaching mathematical skills, especially time which is a very practical skill. There were few clocks for manipulation, or other resources for the encouragement of practical activity.

The lack of organisation and continuity in the time telling environment of the child, together with the apparent difficulty children have in learning about time, implies that there needs to be some order in this area. More attention must be paid to the content and consistency of methods used to teach children to tell time, and information of the relative effectiveness of different approaches, needs to be available. Teaching of time telling should be brought further into the forefront of the primary curriculum, in spite of the failure of the National Curriculum to do this.

6.1.3 Summary Of Findings

An achievement of this study is the exposure of children's time telling abilities as less well developed than previously supposed. Moreover it has been shown that the environment of the school and class, and the teaching environment, are important factors in determining this situation.

In addition, the detailed analysis of children's errors in reading time has highlighted some of the sources of confusion due to the design of our time telling devices. Children have difficulty in processing the information on an analogue clock because of the existence of two hands, the existence of two metrics, the absence of minute numbers, the proportional information of the hour hand, and the use of many variations to express time. The most common confusions are those between the two hands, the two metrics, and the two conjunctions "past" and "to".

A digital clock is difficult to process because of the existence of two sides of the clock, the existence of two numbers on each side of the clock, and the use of many variations to express time. The most common confusions are those between the two sides of the clock, the two digits of the hour or the minute number, and the incorrect application of the conjunctions "past" and "to".

In spite of the findings of this study there is still a great deal to be known about how time telling skills are acquired. The potential benefits of clarification of this process, to teachers and children, are enormous. A number of worthwhile routes for further exploration are suggested.

6.2 FUTURE WORK

6.2.1 How Children Learn To Tell The Time

The work carried out in this study has provided a global overview of the time telling process and environment, and has helped to identify what needs to be pursued. It has shown that the understanding of time telling is a complex process, and that developmental trends are reflected not only in the accuracy of the responses but also in the nature of the errors. A framework for characterizing the strategies that children use to solve time problems needs to be clearly documented in such a way as to make it possible to identify major stages in the acquisition of the skills. Models which characterize the internal cognitive processes that may account for children's behavior are needed. From this, suggestion for how best the teacher can assist his pupils to gain an understanding of time telling, can be made.

A longitudinal method of study would be ideal to provide the greater depth and continuity needed to usefully build upon the knowledge of how children learn to tell time gained through this study. This would highlight the changing character of children's "model" of the clock code. If, in addition, schools were selected according to variation in their teaching strategy for time telling, the effect of certain educational practices on performance, strategies and misunderstandings of pupils, could be assessed.

The fact that so many of the second year junior pupils had not yet mastered the skills measured, suggests that the study of children in the last two years of junior school, in addition to the classes examined in this study, would be a fruitful undertaking.

Since priority was given to the development of a successful and thorough assessment technique for the measurement of time telling skills and the detection of misunderstandings, there is full confidence in the authenticity of the results obtained. For this reason the method developed is proposed as a useful procedure for similar studies in the future, to help increase knowledge of the development of these skills. However, the inherent difficulty of measurement of setting skills is acknowledged.

In addition, the use of a computer analysis programme similar to that specified in this study, is proposed. The automatic coding of errors is extremely advantageous, as they are difficult to code manually on a large scale. Adaptation of the coding system for diagnostic purposes in the classroom is also suggested.

The design of specific tests to probe further particular types of misunderstandings, so that a full taxonomy of errors can be finalised, is suggested. Moreover a thorough explanation of how and why these errors occur, satisfactory remedial procedures and, if possible, avoidance techniques would be an additional goal. Clarification of the general sequence of error occurrence should also throw more light on the sequence of development of understanding of time.

6.2.2 Teaching Resources

Once there is a clearer idea of how it is that children learn time telling skills and how teachers should be approaching this topic, it will be possible to use this information to develop a number of specific teaching resources. In discussions with teachers, the difficulty of determining the level of understanding of each child and so teaching the child as an individual, emerged as one of the most salient problems.

Moreover, the examples of student misunderstandings exhibited here strongly suggest that an instructional programme in time telling must take into account more than the bare facts of the pupil's inability to tell the time. By analysing the child's methods when confronted with a clock to read or set, the teacher will be in a better position to choose specific measures designed to help the youngster overcome his difficulties and raise the level of his competence.

Thus an important practical application of the empiracal work is the production of a diagnostic computer programme, similar in structure to the test already developed, but able to be operated individually by children without the need of help from the teacher. Through this classroom tool, the teacher would be provided with information on the present state of knowledge and understanding, of each child and would thus be in a position to tailor her teaching to the needs of the individual. The computer would allow for the identification of particular problems and thus provide the teacher with the necessary feedback to overcome them.

A similar approach has been taken by a number of researchers with regard to certain mathematical concepts, especially subtraction. A growing number of tutoring systems are being developed which attempt to diagnose pupils' errors and teach by containing clear articulation of the knowledge involved in a chosen domain. Attisha and Yazdani (1983), for example, introduce a knowledge-based tutoring system for diagnosing pupils' errors in subtraction, designed to be of practical use where a pupil can interact with a microcomputer to improve his arithmetic skills. By its informal reasoning abilites, the program is able to quickly predict the precise remediation for the pupil's erroneous answer by providing test problems to identify the exact explanation for the pupil's misconception. It could give more than one explanation to a particular answer for a given problem, since several distinct bugs can generate the same answer, and there can exist a relationship between bugs such that one bug may give rise to another.

As well as the production of a diagnostic programme, it should also be considered how the computer, as an increasingly important addition to classroom teaching facilities, can best serve the purposes of the teacher. The design of more effective and comprehensive computer programs than those presently available, to support class teaching, is proposed.

6.2.3 The Relationship Between The Concept Of Time And Telling Time

Thus, in practical terms, the eventual aim of understanding the way in which children learn to tell time would be the production of a systematic and properly sequenced teaching strategy with effective support materials which could serve to accelerate children's mastery of this problem.

Although any teaching initiative of this kind would properly incorporate reinforcing children's functional understanding of time in relation to their own experience, the possibility would have been created to explore this particular relation more closely. Thus, if it is possible to promote an earlier confidence in dealing with clock time, the advantage of this fluency for thereby reflecting on the natural structure of one's own experience could be evaluated.

There is a more theoretical aim in explaining children's acquisition of time concepts, than the development of a firmer base for good educational practice. Contemporary understanding of how children develop their earliest conceptual knowledge suggests a significance for the typically structured and predictable character of their daily experience (Nelson, 1986). Indeed, children's memory is found to be at its best when reconstructing the narrative of such routines. Muto (1982) considered the properties of children's time concept at the preschool age and found evidence that young children structure their everyday activities according to a "life time script".

It has been proposed that the this "scripted event knowledge" forms the child's foundation for recognizing and forming many new concepts. There is a clear implication that the structure existing within children's typically "scripted" experience is of some developmental importance. If so, we are bound to consider how fluency with the metric of time might reinforce the child's capacity to reflect upon such structure. It is thought likely that internalization of that structure is promoted if a code to summarize it is available. Progress in faciliting children's mastery of time concepts should lead towards a practical consideration of these issues.

APPENDICES

APPENDIX I: A COMPLETED TEST SHEET

INITIALS: KM SUBJ. NO.: 7 SECTION: 1 TEST NO.: 1 CL: 1 SCH: 3

1) Big hand: how many minutes
2) Little hand: all the numbers round the clock
3) Left side of watch: the numbers
4) Right side of watch: the time
5) Watch, A/D: A
6) Clock, A/D: N:

	READ	SET
1)	11 o'clock	11:12
2)	5 o'clock	5 : 12
3)	8 o'clock	8 : 12
4)	1 o'clock	1 : 12
5)	half past	11 : 7
6)	3 o'clock	11 : 3
7)	half past 5	5 : 8
8)	10 to 1	1 : 4
9)	half past 12	12 : 6
10)	10 to 4	10 : 4
11)	10 o'clock	10 :
12)	7 o'clock	7 : 2
13)	half past 6	6 : 9
14)	10 to 9	10 : 9
15)	half past 8	9 : 01
16)	10 to 10	10 : 10
17)	quarter past 6	6 : 6
18)	5 o'clock	5 : 12
19)	10 to 9	9 : 10
20)	12 o'clock	12 : 11
21)	half past 1	2 : 9

1) ~~Big hand~~ / Left side of watch: the time
2) ~~Little hand~~ / Right side of watch: the numbers

APPENDIX II: QUESTIONNAIRE FOR TEACHERS

1) What have you taught your class so far this year, with respect to time?

2) What do you plan to teach your class before the end of the year, with respect to time?

3) Do you teach time: throughout the year, only for a limited period, not at all? As a whole topic and/or generally as a maths topic?

4) What aspects of time do you teach as a whole class activity, in groups, with individuals, a combination of these? Why?

5) a) Do you measure your pupils' knowledge of time when they arrive in your class? How?

   b) What do they know? What is the range?

   c) Do you measure their knowledge at other times? Why? How?

6) Are any aspects of their previous knowledge useful? Are any aspects of their previous knowledge problematic?

7) Is it difficult to decide on a starting point for tutition? Is the level of of your initial tutition based on age/class or do you determine the level by other means?

8) a) What sort of difficulties do your pupils tend to have with telling the time? Do you have any solutions?

   b) What sort of errors do they tend to make? Do you have any ideas as to why they make particular errors eg. hand reversal? Do you try to avoid these? How? Do you try to correct these? How?

   c) Would you appreciate any guidelines on diagnosis and correction of errors?

9) a) What are the time skills you teach to your pupils?

   b) What sequence of the clock, if any, do you present eg. o'clock, half past, etc? and why?

   c) Do you teach any rules (eg. for reading the hour correctly)?

10) a) Do you use a maths scheme? Which one? What is your opinion of it in general? For the teaching of time?

    b) Are there any other sources of ideas you use to teach time?

11) a) What kinds of resources do you use to teach time?

    b) What types of clocks do you use, eg. real, toy, homemade, geared, ungeared, analogue, digital, etc?

12) a) How are the concept of time and telling time taught in relation to each other? What do you think, if anything, is the relationship between the two?

b) Do you teach one after the other? If so which? If you teach them together, how?

c) To what extent, if any, do you think knowledge/understanding of one affects the other? Are there any other factors which might affect the ability to tell the time?

13) a) Do your pupils tend to be more familiar with analogue or digital time when they first arrive in your class? What affect does this have on your teaching? What affect does this have on their learning?

b) Do you teach both the analogue and digital representations of time, or only one? Which one? Why? Do you teach the two together or one after the other? How? Why?

c) Does knowledge/understanding of one affect knowledge/understanding of the other?

d) To what extent, and how, do you relate one to the other in your teaching? ie Do you integrate the two? Can the children relate the two?

e) Is the teaching of only one representation sufficient? Why?

14) a) Are you given any advice as to how to teach time? What sort? From whom/where? Would you like some (more) ?

b) Are there any additional resources you would like made available?

15) a) Does your class have the use of a computer? How much? Is this sufficient?

b) Do you use it for teaching time? How? Why not?

c) If you have used it for teaching time, which programmes have you used? What is your opinion of them? Can you suggest any ways in which they might be improved?

d) Would you like some (more) ideas on how to use the computer to teach time? Would you like some (more) software to teach time? Do you have any suggestions for appropriate, affective software?

16) What are the general problems you experience in teaching time and can you suggest any solutions?

17) a) How do you think children learn to tell the time?

b) Do you have any suggestions as to how learning to tell the time can be facilitated?

c) Would you like more information on how children learn to tell the time? Would you like more information on teaching approaches developed from an understanding of how children come to master this skill?

APPENDIX III: QUESTIONNAIRE FOR MATHEMATICS SPECIALISTS

1) Does your school have a maths policy? Does it include Time?

IF YES: would you describe it as a written policy, an unwritten policy followed by whole staff, or do individual teachers decide how and what they teach for maths?

IF NO: Why do you not have such a policy? and Do you aim to have such a policy?

2) a) To what extent, if any, is the teaching of time integrated across classes? How is this done?

b) Is integration difficult to achieve in practice?

c) Is integration of the teaching of time desirable and important?

3) a) Has your school received any advice this academic year on teaching time? What form has this advice taken? From what sources has it come?

b) What (additional) advice would be useful (if any) on the teaching of time? and from what sources?

4) a) As a school, do you use a scheme or schemes (whether commercial schemes, school based programmes, etc) for the teaching of maths and/or time? If so, which ones? If not, what alternatives do you use?

b) What is your opinion of these schemes to teach maths and/or time?

5) a) What are the computing resources of the school? Are these sufficient?

b) How often are computers available to classes? Is this sufficient?

c) What programmes, if any, does the school have which include work on time?

6) Is there any way in which the teaching of time could be made more efficient in your school?

APPENDIX IV: CODING DISTINCTIONS FOR ANALOGUE READING

THE MINUTE NUMBER OF THE RESPONSE...

0 - correct hand
H - incorrect hand

0 - correct metric
H - incorrect metric

0 - correct laterality
M - mirror image laterality
9 - 90 degree laterality
8 - 180 degree laterality

When the MINUTE metric has been used to generate the minute response number...

0 - correctly computed
1 - one minute computational error
2 - two minute computational error
3 - three minute computational error
4 - four minute computational error
5 - five minute computational error
6 - ten minute computational error
W - way out

0 - no rounding to a 5' sector
N - rounded to nearest 5' sector
F - rounded to further 5' sector

When the HOUR metric has been used to generate the minute response number...

0 - correctly computed
N - nearest rounding
F - further rounding
W - way out

THE HOUR NUMBER OF THE RESPONSE...

0 - correct hand
M - incorrect hand

0 - correct metric
M - incorrect metric

0 - correct laterality
M - mirror image laterality
9 - 90 degree laterality
8 - 180 degree laterality

When the HOUR metric has been used to generate the hour response number...

0 - correctly computed
N - nearest rounding
F - further rounding
W - way out

When the MINUTE metric has been used to generate the hour response number...

0 - correctly computed
1 - one minute computational error
2 - two minute computational error
3 - three minute computational error
4 - four minute computational error
5 - five minute computational error
6 - ten minute computational error
W - way out

0 - no rounding to a 5' sector
N - rounded to nearest 5' sector
F - rounded to further 5' sector

APPENDIX V: EXAMPLE OF CODED DATA

SUBJ.		TARGET		READ	OVERALL	P/T	HOUR	MINUTE		EXTRA
44	7	2	0	2*						
44	7	5	0	5*						
44	7	7	0	7*						
44	7	11	0	11*						
44	7	6	5	6mp 5	:X		x¦RM	x¦RM		
44	7	8	10	8mp10	:X		x¦RM	x¦RM		
44	7	9	15	9 :15	:					
44	7	4	20	4mp20	:X		x¦RM	x¦a		<<<<<
44	7	11	25	5 p11	:X			x¦ M		
44	7	3	30	3mp30	:X		x¦RM	x¦RM		
44	7	12	35	12mp30	:X		x¦	x¦RM		<<<<<
44	7	7	40	7mp40	:X		x¦RM	x¦		<<<<<
44	7	2	45	2mp45	:X		x¦RM	x¦		<<<<<
44	7	10	50	10mp50	:X		x¦RM	x¦ a		<<<<<
44	7	1	55	2mp55	:X		x¦RM	x¦RM		
44	7	8	08	8mp10	::X		x¦	x¦a		=====
44	7	12	13	12 :15	::X			x¦	0	
44	7	2	27	2 :25	::X			x¦	0	
44	7	3	36	3mp35	::X		x¦	x¦		=====
44	7	7	41	7mp40	::X		x¦	x¦		=====
44	7	5	52	5mp50	::X		x¦	x¦	3	=====
14	8	4	0	4*						
14	8	12	0	12*						
14	8	10	0	10*						
14	8	6	0	6*						
14	8	10	5	5mp10	:					
14	8	5	10	25mp 2	:X		x¦R	x¦R		
14	8	3	15	15mp 3	:					
14	8	12	20	20mp 1	:X	.Fp	¦ a			<<<<<
14	8	11	25	25mp11	:					
14	8	6	30	h p 7	:X	.Fp				
14	8	8	35	35mp 9	:X	.Fp				
14	8	2	40	6mp 8	:X		x¦R	x¦		<<<<<
14	8	1	45	45mp 1	:					
14	8	9	50	50mp10	:X	.Np	¦a			<<<<<
14	8	7	55	40mp11	:X		x¦R	x¦	R1	
14	8	11	01	11*	::X			x¦ o		
14	8	2	13	20mp 3	::X		¦a	x¦ M	T	=====
14	8	10	27	24mp10	::X			x¦	3	
14	8	7	34	8mp 8	::X			x¦		=====
14	8	12	49	5mp10	::X		x¦R	x¦	R1	
14	8	1	57	10mp11	::X		x¦R	x¦	R1	

45	10	9	0	9	X			x		0	
45	10	12	0	12*							
45	10	8	0	8*							
45	10	4	0	4*							
45	10	4	5	4 t 1	:X	x	R	x	RM		
45	10	8	10	8 t 2	:X	x	R	x	RM		
45	10	1	15	h p 1	:X			x		h	
45	10	12	20	4*	:X	x	R	x		o	
45	10	9	25	5 t 9	:X			x	M		
45	10	10	30	6 t10	:X			x	M		
45	10	2	35	7 t 7	:X	x	R	x	M		
45	10	5	40	8 t 8	:X	x	R	x	M		
45	10	7	45	9 t 9	:X	x	R	x	M		
45	10	3	50	10 t 3	:X			x	a		<<<<<
45	10	6	55	11 t11	:X	x	R	x	M		
45	10	5	03	h p 5	::X			x		h	
45	10	1	13	q t 2	::X			x		q	
45	10	6	24	h p	::X	x		x		h	=====
45	10	7	39	h p 8	::X		a	x		h	=====
45	10	8	47	h p 9	::X		a	x		h	=====
45	10	11	57	h p11	::X		a	x		h	=====

APPENDIX VI: FEEDBACK FOR SCHOOLS

The present study is concerned with investigating children's understanding of time. The initial focus is on the errors children make in telling the time, in order to discover the way in which they come to master this skill.

It was decided to work with children from infant 3, junior 1 and junior 2, as there is considerable development in time skills across this age span. Ten subjects were chosen at random from each class and a test consisting of two sections was administered to them. Children were alternately given section I or section II first, followed by the other section after a short delay of one or two days.

Each section involved the presentation to the children of a series of 21 times, by means of a computer. Four times on the o'clock, eleven times on each of the five minute points, and six times on any other minute point were given. The children were required to read the time, in one form (either analogue or digital) and set the time in the other form. Then they did the opposite section.

Section I consisted of a series of times presented in analogue form, the subjects were required to read the time and then manipulate a 'digital clock' (by moving magnetic numbers on a board) until both clocks showed the same time. Section II involved the presentation of a series of times in digital format, the reading of these times and the setting of an ungeared analogue clock to the same time.

Two sets of data are provided here as feedback...

VI.1 Summary Data

This shows the number of correct answers by each subject in total (out of 21) and then separately the total for the o'clock section (out of 4), each of the five minute points of the clock (yes/no), and the total of the minute section (out of 6).

There is a separate sheet for each aspect of the test...

i) reading analogue time
ii) reading digital time
iii) setting analogue time (lenient criteria for marking)
iv) setting digital time (lenient criteria for marking)
v) setting analogue time (strict criteria for marking)
vi) setting digital time (strict criteria for marking)

The three classes are shown separately on each sheet. The children are ranked by score within their class.

VI.2 Raw data

For each subject in a class, the times presented, read and set are shown. Children alternately did section I then section II, or section II then section I. The setting of analogue time has been recorded, hour hand, then minute hand, *both* in terms of minutes, so for example 20 0 would indicate the setting of 4:00 exactly.

VI.3 Example of Summary Data

SCHOOL THREE

ANALOGUE READING

Pupil	Total	0	5	10	15	20	25	30	35	40	45	50	55	M
I3 SUBJECT ONE	2	2	.	.	.	.	.	.	.	.	.	.	.	.
I3 SUBJECT TWO	4	3	.	.	.	.	.	Y	.	.	.	.	.	.
I3 SUBJECT THREE	4	4	.	.	.	.	.	.	.	.	.	.	.	.
I3 SUBJECT FOUR	4	4	.	.	.	.	.	.	.	.	.	.	.	.
I3 SUBJECT FIVE	4	4	.	.	.	.	.	.	.	.	.	.	.	.
I3 SUBJECT SIX	4	4	.	.	.	.	.	.	.	.	.	.	.	.
I3 SUBJECT SEVEN	4	4	.	.	.	.	.	.	.	.	.	.	.	.
I3 SUBJECT EIGHT	4	4	.	.	.	.	.	.	.	.	.	.	.	.
I3 SUBJECT NINE	6	4	.	.	.	.	.	Y	.	.	.	Y	.	.
I3 SUBJECT TEN	19	4	Y	Y	Y	Y	Y	Y	.	Y	Y	Y	Y	5
J1 SUBJECT ONE	4	4	.	.	.	.	.	.	.	.	.	.	.	.
J1 SUBJECT TWO	5	4	.	.	.	.	.	.	.	.	.	Y	.	.
J1 SUBJECT THREE	6	4	.	.	.	Y	.	Y	.	.	.	.	.	.
J1 SUBJECT FOUR	11	4	Y	.	Y	Y	Y	Y	.	.	.	.	.	2
J1 SUBJECT FIVE	11	4	Y	Y	Y	.	Y	Y	.	Y	Y	.	.	.
J1 SUBJECT SIX	12	.	Y	.	Y	Y	.	Y	Y	Y	.	.	.	6
J1 SUBJECT SEVEN	14	4	Y	.	Y	Y	Y	Y	Y	Y	Y	.	.	2
J1 SUBJECT EIGHT	18	4	Y	Y	Y	Y	Y	Y	Y	.	.	Y	Y	5
J1 SUBJECT NINE	20	4	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	5
J1 SUBJECT TEN	20	4	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	5
J2 SUBJECT ONE	1	.	.	.	.	.	.	.	.	.	.	Y	.	.
J2 SUBJECT TWO	4	4	.	.	.	.	.	.	.	.	.	.	.	.
J2 SUBJECT THREE	12	4	.	Y	Y	Y	Y	Y	.	.	.	.	.	3
J2 SUBJECT FOUR	15	4	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	.
J2 SUBJECT FIVE	16	4	Y	Y	Y	Y	Y	Y	Y	Y	Y	.	Y	2
J2 SUBJECT SIX	17	4	Y	.	Y	Y	Y	Y	.	Y	Y	Y	Y	4
J2 SUBJECT SEVEN	17	4	Y	Y	Y	Y	Y	Y	Y	Y	.	.	.	5
J2 SUBJECT EIGHT	19	4	.	Y	Y	Y	Y	Y	Y	Y	Y	Y	.	6
J2 SUBJECT NINE	21	4	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	6
J2 SUBJECT TEN	21	4	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	6

VI.4 Example of Raw Data

SCHOOL 4 INFANT 3 SUBJECT 1

SECTION I: READING ANALOGUE TIME, SETTING DIGITAL TIME

GIVEN		READ			SET		
11	0	11 *			11	:	12
12	0	12	t	12	12	:	12
5	0	5 *			12	:	5
6	0	6 *			12	:	6
4	5	4	t	1	14	:	
10	20	10	t	4	4	:	01
11	40	8	t	12	81	:	2
7	35	7	t	7	77	:	
1	45	9	t	2	92	:	
3	50	10	t	4	10	:	4
12	25	5	t	12	51	:	2
8	55	9	t	11	11	:	9
6	15	6	t	3	36	:	
2	30	6	t	2	26	:	
9	10	9	t	2	29	:	
12	33	6	t	12	12	:	6
7	14	7	t	3	73	:	
9	43	8	t	9	98	:	
1	1	12	t	1	12	:	1
11	24	11	t	5	11	:	5
6	51	7	t	10	10	:	7

SECTION II: READING DIGITAL TIME, SETTING ANALOGUE TIME

GIVEN	READ			SET	
9: 0	19 *			45	0
6: 0	60 *			30	0
2: 0	20 *			0	0
4: 0	40 *			54	54
11:30	11	:	30	50	51
6:15	15	:	60	1	51
12: 5	21	:	50	0	54
5:25	25	:	52	45	0
2:45	20	t	45	5	5
3:50	30	t	50	55	55
1:55	22			55	55
8:40	40	t	8	39	39
10:35	10	:	32	10	11
4:20	20	t	4	20	20
9:10	10	t	9	51	55
5:39	50 m	p	39	50	50
6:42	60 m	p	42	40	44
4:59	40 m	p	59	54	55
10:29	29	t	10	1	0
3:12	30 m	p	12	51	55
1: 3	10	t	30	55	1

APPENDIX VII: DESCRIPTION OF ERRORS

Errors made in the four tasks were identified informally through observation of subjects during testing. There is some overlap, but errors are mainly specific to their task and so must be classified separately. In consideration of the following errors it is essential to bear in mind that whilst they can occur singly, they are often to be found in combination with each other, thus the resulting error possiblities are almost endless. Errors are listed below in supposed order of prevalence in this study. This distribution of error occurrence is thought to be reasonably representative of any population of children from a mixture of school types, though it will obviously be affected by a number of factors, including age, intelligence, school and home environment, teaching methods used, etc.

Errors will be considered under the following five categories...

1) General Errors
2) Errors Specific to Reading Analogue Time
3) Errors Specific to Reading Digital Time
4) Errors Specific to Setting Analogue Time
5) Errors Specific to Setting Digital Time

VII.1 GENERAL ERRORS

i) Wrong: Analogue reading: Children sometimes appear to guess all or part of the answer. For reading, it is assumed that the few answers that cannot otherwise be accounted for, are due to guesses. When setting, children Sometimes move the hands aimlessly around the clockface, clockwise and anticlockwise, stopping and starting, perhaps hoping for feedback from the tester, or just seeing what looks reasonable. Digital reading: In a few cases, children seemed to simply read the time incorrectly. There was no discernable strategy in operation and the times read bore no recognisable relationship to those given.

ii) Familiar Times: Some times are more familiar to children than others, either because they have been much repeated in teaching, or because they are easy to learn for some intrinsic reason, for example at 12:00 both hands point to the 12, or because they have a particular significance for an individual, class, school, or all children. Children are more likely to give a familiar answer, if the shape of the hands is familiar, than stop to consider that it might be something else. This error is more applicable to reading, as this is a more familiar activity for most children, but it does have some relevance to setting as well. For example, children tend to say "9 o'clock" for 11:45 because o'clocks are looked for first, it is not that children have actually reversed hands. The reversed mistake of saying "quarter to 12" for 9 o'clock is unlikely to be made.

iii) Application Of Knowledge To More Advanced Situations: Children seem to apply their knowledge, even in situations that exceed it, for example if they know only o'clock and half past, they might use these all the way through the test. It would seem that at an elementary level of this strategy, they seem unaware that they are making any error, whereas later on, children realise that their answer is not applicable, but do not have any wider knowledge to draw upon. This should be verified empirically as should the ways in which they apply their knowledge. For example, whether children just use "half past" whenever the time is not an o'clock, or whether they use both and apply them when they seem to fit best. Types of this error include inappropriate and repetitive use of o'clock, half past, quarter past, quarter to, and idiosyncratic times.

iv) **Saying A Nonsense Time:** Eg. "11", "half past", "5 minutes", or "80 hours and 20 hours".

v) **Associations:** Common and Idiosyncratic. For example the number four can be asociated with a quarter.

vi) **Errors Due To Materials Used:** For example, on the real analogue clock used in the study, the number 10 was slightly off the corresponding minute mark. For this reason children often st time on the 51 minute point when they meant to set it pointing at the hour number 10.

VII.2 ERRORS SPECIFIC TO ANALOGUE READING

i) **Reversing The Hands:** The hour hand is read as if it were the minute hand and the minute hand is read as if it were the hour hand.

ii) **Reading The Hour Metric Only:** Can either do this 'correctly', for example 4:15 would be read as "3 past 4" or 6:55 would be read as "11 to 7", or more often, in combination with other errors, eg. reading the wrong hour - 6:55 is read as "11 to 6". The conjunction "to" is most commonly used when the hour metric only is used, and in the majority of cases this is a more primitive stage than the use of the conjunction "past". However there is also a more advanced use of the conjunction "to" which tends to follow after the use of "past".

7:50 can be read as "10 to 8". In such a case, it is impossible to distinguish a correct answer from the use of the hour metric only, so that many answers appear correct when they are not.

iii) **Reading The Hour Incorrectly:** For all times (except o'clocks) there are two hour numbers that can be read, the lower one with the minutes past that hour, or the higher one with the minutes to that hour. For this reason, whether the hour is correct or not depends on the conjunction used. There are two types of this error...

> a) Reading the nearest adjacent hour compatible with the "to" conjunction, when the "past" conjunction has been used: Increasingly occurs as the hour hand nears the next hour, for each hour, so more likely after 30 minutes past the hour. Eg. 7:45 is read as 8:45 or 45 minutes past 8 [nb. can also be read as qt7]
>
> b) Reading the further adajacent hour compatible with the "past" conjunction, when the "to" conjunction has been used: For example 7:45 is read as "quarter to 7".

iv) **Reading The Minute Incorrectly:** Errors of this type are best clarified by careful attention to the way in which a child counts when asked to read a particular time, otherwise their origins can be ambiguous. There are eight types of this error...

a) Counting incorrectly.

b) Counting five minutes for every one minute: For example, 3:05 is read as "25 past 3". 7,29

c) Counting one minute for every five minutes: For example, 3:20 is read as "4 past 3" (could also be due to reading hour metric only).

d) Counting minutes as hours.

e) Counting hours as minutes.

f) Counting two or more units as minutes between each minute mark: For example 3:05 is read as "8 minutes past 3".

g) Miscounting...

i) By five minutes when counting in fives: Either over counting or under counting.

ii) By ten minutes when counting in fives: Either over counting or under counting.

ii) By more than ten minutes when counting in fives: This cannot be verified unless it is clear exactly what the child has done, as this error starts to be confused with many other error types.

iv) By one minute when counting in ones.

v) By two minute when counting in ones.

vi) By three minute when counting in ones.

vii) By four minute when counting in ones.

viii) By five minute when counting in ones.

ix) By six or minutes when counting in ones.

It is common to compound the two errors of miscounting by five and by one, because a child often counts by both methods in sucession when the time presented is on a one minute point, so he may finally have miscounted by eg. 6 minutes, in two separate stages. This must be verified by observing the child identifying the time.

h) Counting round the clock a second time: Counting right round the clock and continuing round a second time eg. 09:01 is read as "61 m p 9". This would be accepted as correct if read as "61 minutes past 8".

v) Past/To Confusions And Mirror Images.

vi) Reading Hour Metric And Multiplying By A Factor Of Ten: This applies only to hour numbers 1-9. Eg. 1:15 is read as "1:30". In many cases such errors are dubious in origin, they could also be due to other factors such as to mirror images of the minute hand, and miscounting of minutes, but they are assumed to be a multiplication by ten as this is thought to be more common, unless there is additional evidence to suggest otherwise. There are three types of this error...

a) Minute hand only: for example 1:15 is read as "1:30".

b) Minute and hour hands: for example 1:15 is read as "30 past 10".

c) Hour hand only: for example 1:15 is read as "15 minutes past 10".

vii) **Reading Minute Metric Only:** This can be of three types...

a) Using exact position of hour hand.

b) using nearest hour number.

c) using further hour number.

viii) **Reading One Hand Only:** Either the minute or the hour hand. The minute hand is read more often as it is bigger and in the target times given in these tests, it was more often exactly on a five minute mark. Some children changed their strategy when they were given times off the five minute marks. Either just using the one number, or manufacturing a conventional two part time, by... how far hand is past the hour number, eg. 12:16 read as 1 minute past 3. Of two types... a) minute hand, b) hour hand.

ix) **Errors Based On Angle:**

a) between minute hand and hour number - children derive the minute number from the number of minutes the minute hand is past the last hour number.

b) between the hands - children derive the minute number from the number of minutes the minute hand is past the hour hand.

VII.3 ERRORS SPECIFIC TO READING DIGITAL TIME

i) **Just Reading The Digits:** The most elementary error in reading digital time. The child does not recognise that there are two separate parts to the time. Digits can be read...

a) Correctly: For example 09:57 is read as "0,9,5,7".

b) Incorrectly: By omitting the first, second, third or fourth digit, or some combination of these; by reversing the first with the second digit, the third with the fourth digit.

ii) **Reversal Of:**

a) The hours with the minutes: eg. 09:35 may be read as "9 mintes past 35".

b) The two hour numbers when one of them is zero: For example

07:15 is read as "70:15".

c) The two hour numbers when neither of them is zero: For example 12:15 read as "21:15".

d) The two minute numbers when one of them is zero: For example 12:04 is read as "12:40".

e) The two minute numbers when neither of them is zero: For example 12:54 is read as "12:45".

iii) Ommitting Some Digits:

a) Second minute digit: Eg. 12:35 is read as "3 minutes past 12".

b) First minute digit: Eg. 12:35 is read as "5 past 12".

c) Both minute digits: Eg. 12:35 is read as "12".

d) First hour digit: Eg. 12:35 is read as "2:35".

e) Both hour digits: Eg.12:35 is read as "35".

f) Second hour digit: Eg. 12:35 is read as "1:35".

iv) Addition Of:

a) The two minute digits to make another number: For example 02:37 is read as "10 minutes past 2".

b) The two hour digits to make another number: For example 12:37 is read as "37 minutes past 3".

c) Digits across the colon: Two types... a) Addition of digits across the colon: For example 09:02 is read as "11" or "11 minutes", and b) Combination of digits across the colon: For example 09:02 read as "29 minutes past".

VII.4 ERRORS SPECIFIC TO SETTING ANALOGUE TIME

i) Errors Involving zero: ie place value confusions.

ii) Use Of Only One Side Of The Clock: The setting of both the hour and minute aspects of the time on one side of the colon only.

iii) Addition Of Numbers.

iv) Spread Of Numbers Over The Colon: The setting on both sides of the clock, of a number that belongs exclusively on one side.

v) Exact Position Of The Hour Hand: Only five subjects placed the hour hand in the correct position between two hour numbers, except as an inaccurate error when meaning to place hand exactly on an hour number. Otherwise hands were always placed exactly on an hour numeral.

vi) Ommitting Some Digits: For example, 06:50 is set as '30 25', instead of '30 50'.

VII.5 ERRORS SPECIFIC TO SETTING DIGITAL TIME

i) REVERSAL OF...

a) The two hour numbers: For example 12:00 is set as 21:00. This is more common when a zero is involved, for example, 07:15 is set as 70:15, it is a place value problem.

b) The two minute numbers: For example 12:54 is set as 12:45.

c) The hours with the minutes: This is very common. Time tends to be set in the order in which it is read, eg. if time has been read as "35 minutes past 9", it seems more likely to be set as eg. 35:90 than if it had been read as "9:35". Children don't seem to be sure that hours are on the left of the colon and minutes are on the right.

ii) **Ommitting Some Digits:** eg. 08:34 might be set as only 80:00 or 00:80.

iii) **Wrong/Setting Digits Not Present:** eg. setting 03:00 as 30:12 (this adding of 12 minutes is specific to o'clock times) or eg. 04:50 as 04:40 due to a practical setting error rather than a misunderstanding.

iv) **Dividing The Minute Digits To Make Another Number:** This often seems to occur when child wants to set eg. 11 but finds this cannot be done in a single digit box of the clock and so divides 11 into 9 and 2, so sets eg. :92.

v) **Adding Hour Digits To Make Another Number:** This occurs for the same reason as described above for minute digits.

vi) **Setting Numbers Which Span Over The Two Sides Of The Colon:** eg. read "3 o'clock" and set as 31:20, meaning 03:12, though there may be other reasons for this sort of error.

vii) **Setting Hour Metric Only.**

viii) **Setting Minute Metric Only.**

APPENDIX VIII: LIST OF PRIMARY SOFTWARE ON TIME

This is a list of the software concerned with time, discovered in the course of this study. It is clearly extensive, yet only the few programs marked with an asterix were actually found to be used in the six schools visited.

Programmes Directly Covering Time Telling

Basic Mathematics
Clock (The BBC Microcomputer Disc System)
* Clock!
Clocks (Microspecial Pack)
Educational-1
Estimation
Estimation: Time Flies
* Four Funtime Programmes
Ginn Microcomputer Software:
* "Time Puzzles"
"Time Journey"
"Before and After"
Hours
Master Time
Primary Maths Software Box: Timetrucker
Primaths5 (Clock)
Right on Time
Scottish Microelectronics Development Programme:
"Clocks"
"Timetables"
Timeman One
Timeman Two

Programmes Indirectly Covering Time

Amazing Ollie: Beat The Clock
Beat The Bus
Boiled Eggs
Distance Time Graph
Let's Explore London
Let's Explore Paris
Maths in Motion (Cars)
Maths Master (Time)
Motion
Oil Deliveries
Physics Fun Programmes: Estimate
Primary Energy Game ("PEG")
Read-Right-Away 2A: Soundsport
Round The World
Run Around
Weatherplot

Adventure Games Involving Time

Adventure Island
Cuthbert Catches A Cold
Magic Clock
Mathemagic Land
Mickey's Magic Mixture
Planet Patrol
The Wizard's Return
The Wizard's Revenge
Time Quest
Town (Norric)
* Wrecker's Rock
Zoopak

Historical Programmes

Canal Builder
Dinosaurs
Domesday Database
Fletcher's Castle
Hereward The Rebel
How We Used To Live 1874-87
How We Used To Live 1902-26
How We Used To Live 1836-53
How We Used To Live 1854-70
Myself
Sir Francis Drake
The Knight
The Thegn
Time Lines
Time Traveller's London

Assessment Programmes

Practical Assessment Of Mathematics

Programmes On Angles

Angle
Basic Mathematics
Primary Maths Course

Programmes On Fractions

Basic Mathematics
Shipwreck Junior

APPENDIX IX: DESCRIPTION OF PRIMARY SOFTWARE ON TIME

Programmes Directly Covering Time

Title: MATHEMATICS, LEVELS 1-7
Subject: VARIOUS
Summary: Telling the time in hours, half hours and quarter hours; addition of time; interpreting a line graph based on time.
Age: 7-9+
Publisher: GINN & CO. LTD.
Source: GINN & CO. LTD., EDUCATIONAL PUBLISHERS, PREBENDAL HOUSE, PARSON'S FEE, AYLESBURY, BUCKS. HP20 2QZ.
Price: £17.95

Title: TIME PUZZLES (LEVEL 3)
Subject: ORDERING CLOCKS, IN WHOLE, HALF AND QUARTER HOURS
Publisher: GINN MATHS 1986
Source: GINN MICROCOMPUTER SOFTWARE

Title: TIME JOURNEY (LEVEL 3)
Subject: READING CLOCKS AND PLANNING JOURNEYS
Publisher: GINN MATHS 1986
Source: GINN MICROCOMPUTER SOFTWARE

Title: BEFORE AND AFTER (LEVEL 4)
Subject: 5 MINUTE INTERVALS, DIGITAL AND ANALOGUE CLOCKS
Age: 8+
Publisher: GINN MATHS 1986
Source: GINN MICROCOMPUTER SOFTWARE

Title: TIME TRUCKER
Subject: RELATIONSHIP BETWEEN 12 HOUR ANALOGUE AND 24 HOUR DIGITAL CLOCK
Summary: Three games of strategy which help understanding of the relationship between the 12 hour analogue clock and the 24 hour digital clock. The player drives a truck around a grid, collecting and delivering as many orders of farm produce as possible in a specified time, and earning money. There are three maps and a variety of hazards to overcome on the journey. The player must develop a strategy involving factors of time, cost and distance. There are reward sequences and three grades of the game.
Age: 8-14
Publisher: ESM
Source: ESM, DUKE STREET, WISBECH, CAMBS. PE13 2AE. TEL: 0945 63441.
Price: £9.95 + VAT

Title: EDUCATIONAL-1
Subject: CLOCK-TELLING TIME
Age: 5+
Publisher: GOLEM
Source: MICRO EXPRESS LTD

Title: MICROSPECIAL PACK
Subject: CLOCKS
Age: 8+
Publisher: COLLINS/HILL McGIBBON
Source: MESU BRIEFING 1987

Title: MASTER TIME
Subject: TELLING THE TIME, 12 AND 24 HOUR CLOCKS, DIGITAL AND ANALOGUE.
Summary: There are various levels of difficulty, say and set time options and a testing section on digital time.
Age: 7-11
Publisher: ED.SOFT
Source: ED.SOFT, 67 WINSTON ROAD, EXMOUTH. EX8 4LR. TEL: 0395 270128
Cost: £11.75

Title: HOURS
Subject: TEACHES AND REINFORCES TELLING ANALOGUE O'CLOCK TIMES.
Publisher: MUSE 1982
Source: MUSE, PO BOX 43, HOUGHTON-ON-THE-HILL, LEICS. LE7 9GX. TEL: 0533 433839
Price: £2.50

Title: ESTIMATION
Subject: A SERIES OF SIX PROGRAMMES ON ITEMS, LENGTH, TIME, ANGLE, AREA AND PERIMETER
Age: 7-11
Publisher: HODDER & STOUGHTON 1986/7
Source: HODDER & STOUGHTON, MILL ROAD, DUNTON GREEN, SEVENOAKS, KENT. TN13 2YA. TEL: 0732 450111.
Price: £24.00 + VAT

Title: CLOCK!
Subject: PRACTICE IN TELLING TIME THROUGH AN ASSOCIATION BETWEEN THE 12 HOUR CLOCK DISPLAY AND DIGITAL AND VERBAL EXPRESSION OF TIME.
Summary: Shows time on a static or moving clock, with or without a corresponding digital or verbal display; tests ability to express time in digital or verbal form at three levels of difficulty; tests ability to set clock.
Age: 5-9
Publisher: MJP (MICHAEL JAY PUBLICATIONS) 1986
Source: MJP, MICHAEL JAY PUBLICATIONS, PO BOX 23, ST. JUST, CORNWALL. TR19 7JS. TEL: 0736 787808
Price: £13.95 + VAT

Title: RIGHT ON TIME (ALSO ELECTRONIC BOOK VERSION)
Subject: PRACTICE AND GUIDANCE IN TELLING TIME - ANALOGUE AND DIGITAL CLOCKS.
Summary: Pupils set a clock or watch to a specified time. Digital time relates to an event eg. a T.V. programme. Help given if needed. Rewards for correct answers also relate to time eg. sand passing through a timer. At the end of one programme pupil can estimate the time taken.
Age: 7-REMEDIAL 11
Publisher: DACO SOFTWARE 1986
Source: DACO SOFTWARE, 59 MACKENZIE ROAD, BIRMINGHAM. B11 4EP. TEL: 021 449 2253
Price: £12.50 + VAT

Title: EDUCATIONAL 1
Subject: PROGRAMMES ON COUNTING, MATHS, SPELLING AND TELLING THE TIME.
Summary: "Clock" - write the time displayed on the clock, set the time given by moving the hour and minute hands. Four levels of difficulty.
Age: 5-9
Publisher: GOLEM
Source:
Price: £8.95

Title: TIMEMAN ONE
Subject: TELLING THE TIME AND SETTING THE CLOCK
Summary: Option of progressive stages: telling hours, minutes, hours and minutes, and setting time. Incorrect answers allow another chance with guidance. Happy/sad faces show right/wrong answers and a figure climbs a ladder and plants a flag to reward sufficient correct answers. Minutes can be set to 1 or 5 minute accuracy. Can monitor individual performances to allow identification of problem areas.
Age: 4-9 AND SEN
Publisher: BOURNE EDUCATIONAL SOFTWARE
Source: MICRO EXPRESS LTD 1987
Price: £8.65-£32.50

Title: TIMEMAN TWO
Subject: FOLLOWS TIMEMAN ONE.
Summary: 24 hour clock, minutes to the hour and quarter past, half past and quarter to the hour. Option of 1 or 5 minute accuracy. Full progress-monitoring facilities. Explanatory booklet.
Age: 4-10
Publisher: BOURNE EDUCATIONAL SOFTWARE
Source: MICRO EXPRESS LTD 1987
Price: £8.65-£32.50

Title: CLOCKS
Subject: PRACTICE AND REINFORCEMENT IN TELLING AND SETTING TIME, ANALOGUE AND DIGITAL, 12 AND 24 HOUR CLOCKS.
Summary: Graded practice to familiarise pupils with the variations of presenting and recording time. Specifically test ability to: tell time on a 12 hour clock - on the hour, half hour, quarter past and quarter to, at 5, 10 and 20 past and to, and at 5 minute intervals; relate this to digital, 12 and 24 hour modes; understand and use a variety of written forms of time; set clock using 12 and 24 hour modes. Pupils must have mastered simple time telling, and know the difference between the 12 and 24 hour clock. The should be able to read and understand the words and numbers on the concept keyboard.
Age: 10-14 14-16
Publisher: SCET 1985
Source: SCET, COLLINS EDUCATIONAL, FREEPOST, GLASGOW G4 OYX. TEL: 041 772 3200.
Price: £17.50

Title: BASIC MATHEMATICS
Subject: A SUITE OF EIGHT PROGRAMMES INCLUDING TELLING AND SETTING TIME
Summary: To provide practice in setting the clock and writing times in am/pm notation as well as in 24 hour notion.
Age: 5-9
Publisher: SCETLANDER LTD. 1987
Source: SCETLANDER LTD., SPECIAL NEEDS SOFTWARE LTD., 74 VICTORIA CRESCENT ROAD, GLASGOW. G12 9JN. TEL: 041 357 1659.
Price: £20.00 + VAT

Title: CLOCKS (MICROSPECIAL PACK)
Subject: TIME
Age: 8+
Publisher: COLLINS/HILL McGIBBON
Source: MESU BRIEFING 1987

Title: ESTIMATION PROGRAMS ON SIX SUBJECTS, INCLUDING "TIME FLIES"
Subject: ESTIMATION OF TIME
Summary: Estimate time of one repeated activity. Allows children as many tries as necessary.
Age: 7+
Publisher: UNIVERSITY OF LONDON - INSTITUTE OF EDUCATION (ULIE) WITH HODDER & STOUGHTON

Title: FOUR FUNTIME PROGRAMS
Subject: READING AND SETTING ANALOGUE AND DIGITAL TIME
Summary: Four options: Set the clock hands - Analogue, Set the clock hands - Digital, Analogue time, Digital time

Title: SCOTTISH MICROELECTRONICS DEVELOPMENT PROGRAMME
Subject: 25 PROGRAMS FOR SLOW LEARNERS COVERING A VARIETY OF LIFE AND SOCIAL SKILLS.
Summary: "Clocks", "Timetables": reading bus timetables
Publisher: SCOTTISH MICROELECTRONICS DEVELOPMENT PROGRAMME

Title: CLOCK (THE BBC MICROCOMPUTER DISC SYSTEM)
Subject: DISPLAY CLOCKS
Summary: Working display clocks. Four options: Analogue display, Digital display, Analogue and digital display, reset time.

Title: PRIMATHS5
Subject: FIVE PROGRAMMES INCLUDING "CLOCK"
Age: 9-11
Publisher: MUSE 1982
Source: MUSE, PO BOX 43, HOUGHTON-ON-THE-HILL, LEICS LE7 9GX. TEL: 0533 433839

Programmes Indirectly Covering Time

Title: DISTANCE TIME GRAPH
Subject: GRAPHS, SPEED, DISTANCE.
Age: 10+
Publisher: GINN MATHS
Source: GINN MICROCOMPUTER SOFTAWARE

Title: ROUND THE WORLD
Subject: TIMETABLES
Age: 9+
Publisher: GINN
Source: GINN MICROCOMPUTER SOFTAWARE

Title: LET'S EXPLORE LONDON
Subject: TIMETABLES, GUIDEBOOKS, MAPS.
Age: 8+
Publisher: CAMBRIDGE SOFTWARE HOUSE
Source: B.B.C. ED SOFTWARE DIRECTORY 87

Title: LET'S EXPLORE PARIS
Subject: TIMETABLES, GUIDEBOOKS.
Age: 8+
Publisher: CAMBRIDGE SOFTWARE HOUSE
Source: B.B.C. ED SOFTWARE DIRECTORY 87

Title: MATHS IN MOTION (CARS)
Subject: GRAPHS, PLANNING, LOGICAL THINKING.
Age: 9+
Publisher: CAMBRIDGE SOFTWARE HOUSE
Source: B.B.C. ED SOFTWARE DIRECTORY 87

Title: OIL DELIVERIES
Subject: ROUTE PLANNING, TIME FACTORS, SCHEDULES.
Age: 8+
Publisher: FERNLEAF
Source: B.B.C. ED SOFTWARE DIRECTORY 87

Title: RUN AROUND
Subject: CAR JOURNEY, DISTANCE, TIME, SPEED.
Age: 8+
Publisher: DERBYSHIRE ED SOFTWARE CENTRE.
Source: RESOURCE.

Title: WEATHERPLOT
Subject: GRAPH, WEATHER.
Age: 7+
Publisher: DERBYSHIRE ED SOFTWARE CENTRE.
Source: RESOURCE.

Title: BEAT THE BUS
Subject: READING AND COMPREHENDING SIMPLE TIMETABLES
Summary: Encourages decision-making skills by simulating a journey by bus and on foot, from home to school/work. Decisions about time, money, energy and time of arrival of the next bus must be made. Several difficulty levels.
Age: 13-16
Publisher: MJP (MICHAEL JAY PUBLICATIONS) 1986
Source: MJP, MICHAEL JAY PUBLICATIONS, PO BOX 23, ST. JUST, CORNWALL. TR19 7JS. TEL: 0736 787808.
Cost: £13.95 + VAT

Title: PHYSICS FUN PROGRAMMES
Subject: ESTIMATION OF TIME
Summary: Five programss including "Estimate": Estimation of length, area, volume and time
Age: 11-16
Publisher: AUDIO VISUAL PRODUCTIOS (AVP) 1986
Source: AVP COMPUTING, HOCKER HILL HOUSE, CHEPSTOW, GWENT. NP6 5ER. TEL: 02912 5439
Cost: £13.50-24.50 + VAT

Title: MOTION
Subject: SIX PROGRAMMES COVERING THE ESTIMATION OF LENGTH, TIME & SPEED
Age: 13-16
Publisher: AUDIO VISUAL PRODUCTIOS (AVP) 1986
Source: AVP COMPUTING, HOCKER HILL HOUSE, CHEPSTOW, GWENT. NP6 5ER. TEL: 02912 5439
Cost: £13.50-15.70 + VAT

Title: PRIMARY ENERGY GAME ('PEG')
Subject: USE OF TIME
Summary: Players score according to how well they use energy in PEG's house. External factors such as time, changing weather and the random opening of windows, influence the internal temperature of rooms.
Age: 8-13
Publisher: BRITISH GAS EDUCATION SERVICE (BGES)
Source: BGES, PO BOX 46, HOUNSLOW, MIDDLESEX. TW4 6NF. TEL: 01 759 4611
Cost: £9.20 + VAT

Title: MATHS MASTER
Subject: GRAPHS
Summary: Pupils work towards achieving the title of Maths Master. They choose from questions on time, money or area. Questions are offered at random and are at junior level. The questions on time involve the reading of a graph of the flights of two aeroplanes.
Age: 7-13
Publisher: GSN EDUCATIONAL SOFTWARE 1986
Source: GSN EDUCATIONAL SOFTWARE, 50 STAMFORD STREET, ASHTON-UNDER-LYNE, LANCASHIRE. OL6 7LP. TEL: 061 339 6635
Cost: £12.50 + VAT

Title: READ-RIGHT-AWAY 2A
Subject: 2 PROGRAMMES INCLUDING "SOUNDSPORT"
Summary: Covers word endings 'st' 'sp' 'ck' etc. The player's sportsmen compete against each other and the clock in four events.
Age: 6-9
Publisher: HS SOFTWARE

Title: AMAZING OLLIE
Subject: FOUR OPTIONS INCLUDING "BEAT THE CLOCK" & "ADVANCED OPTION"
Summary: The user has 80 seconds to catch fish and return to the children. A good strategy is the key to sucess.
Age: 4-8
Publisher: STORM SOFTWARE

Title: BOILED EGGS
Subject: USE OF TIME, PROGRAMMING
Publisher: PRIMARY MATHS AND MICROS MEP

Adventure Programmes Involving Time

Title: ADVENTURE ISLAND
Subject: PROBLEMS, TIME
Age: 9+
Publisher: GINN MATHS 1986
Source: GINN MICROCOMPUTER SOFTWARE

Title: MAGIC CLOCK
Subject: AN ADVENTURE GAME TO SIMULATE CREATIVE WORK AND DEVELOP PROBLEM SOLVING SKILLS
Summary: The user takes the role of Charlie, the hero, who travels back in time to 'Cowboy Land' with the help of the magic clock' He meets characters, overcomes problems and ultimately finds the clock which will return him to his bedroom.
Age: 6+
Publisher: RESOURCE 1987
Source: RESOURCE, EXETER ROAD OFF COVENTRY GROVE, DONCASTER. DN2 4PY.
TEL: 0302 63800/63784
Cost: £14.95

Title: MICKEY'S MAGIC MIXTURE
Subject: ADVENTURE WITH VARIOUS MATHS SKILLS
Summary: A four-part text adventure (with some graphics) which aims to put mathematical skills in context. Includes problems on time. An amusing but mathematically demanding adventure. Group decisions are important.
Age: 8-12
Publisher: SELECTIVE SOFTWARE
Source: MICRO EXPRESS LTD

Title: THE WIZARD'S RETURN
Subject: A MATHEMATICAL ADVENTURE ON TWO DISCS: PART 1 (20-30 MINUTES), PART 2 (60-90 MINUTES)
Summary: To rescue the Dragon King the children must solve a series of problems which appear in a random sequence. Story booklet should be read first. Two difficulty levels. Sequel to the Wizard's Revenge, but also self-contained.
Age: 9-11
Publisher: SHERSTON SOFTWARE

Title: WIZARD'S REVENGE
Subject: AN ADVENTURE PROGRAMME (40-90 MINUTES) WHICH INCLUDES TIME
Summary: The children are asked to help rescue a mythical king who is imprisoned on his own island by a wicked wizard. Children face problems on a variety of mathematical topics including time.
Age: 7-11
Publisher: SHERSTON SOFTWARE

Title: CUTHBERT CATCHES A COLD
Subject: TIME, NUMBER, LANGUAGE, ETC
Summary: A complete class activity package involving Cuthbert the Dinosaur. There is a three part adventure including time, number, language, etc. Also many additional resources.
Age: 6-9
Publisher: SELECTIVE SOFTWARE

Title: TIME QUEST
Subject: TIME PROBLEMS
Summary: An adventure programme designed to form the core of a topic on time. Children must elude the Time Sprite by solving a number of problems concerning time.
Age: 6-8
Publisher: MEDUSA 1986
Source: MICROELECTRONICS EDUCATION DEVELOPMENT UNIT, MEDUSA, BISHOP GROSSETESTE COLLEGE, NEWPORT, LINCOLN. LN1 3DY. TEL: 0522 44713
Cost: £10.00

Title: ZOOPAK
Subject: AN ADVENTURE PROGRAM WHICH INCLUDES TIME
Summary: A package of cross-curricular resource materials intended as the major part of a Zoo project. Particularly suitable for children as three of the programs are virtually text free. There are three problem solving programs. One is Petra's Dream. Children must find Petra, feed the animals at the right time, with the right food, in the right cages and rescue them from the burning Zoo.
Age: 5-10
Publisher: 4 MATION EDUCATIONAL RESOURCES

Title: MATHEMAGIC LAND
Subject: MATHS PROBLEMS
Summary: A maths adventure game in which children have to solve problems in order to rescue the king's children from the evil Sly Drool. Three levels of difficulty. The numbers change each time a scene is visited.
Age: 10-16
Publisher: L.T.S.

Title: WRECKER'S ROCK
Subject: ADVENTURE INVLOVING READING TIMETABLES
Summary: Gives experience in decision making, problem solving and research (including reading bus timetables). Knowledge of the 24 hour clock is necessary. Takes 20-45 minutes.
Age: 9-13
Publisher: HOLMES MACDOUGALL SOFTWARE 1986

Title: TOWN (NORRIC)
Subject: AN ADVENTURE INVOLVING TIME
Summary: The player has a fixed sum of money and must travel from home to town to meet friends at a set time. On the way there are a number of incidents which demand a reaction. On completion of the journey there is a summary and a questionnaire.
Age: 7-13
Publisher: NORTHERN MICROMEDIA

Historical Programmes

Title: FLETCHER'S CASTLE
Subject: NORMAN HISTORY
Age: 8+
Publisher: FERNLEAF
Source: EDUC. SOFTWARE FOR B.B.C. MICRO

Title: THE KNIGHT
Subject: NORMAN HISTORY
Age: 8+
Publisher: FERNLEAF
Source: EDUC. SOFTWARE FOR B.B.C. MICRO

Title: THE THEGN
Subject: NORMAN HISTORY
Age: 8+
Publisher: FERNLEAF
Source: EDUC. SOFTWARE FOR B.B.C. MICRO

Title: DINOSAURS
Subject: HISTORY
Age: 7+
Publisher: CAMBRIDGE SOFTWARE HOUSE
Source: EDUC. SOFTWARE FOR B.B.C. MICRO

Title: CANAL BUILDER
Subject: YEAR 1790
Age: 7+
Publisher: AVP COMPUTING
Source: EDUC. SOFTWARE FOR B.B.C. MICRO

Title: SIR FRANCIS DRAKE
Subject: ADVENTURE GAME
Age: 8+
Publisher: LCL
Source: EDUC. SOFTWARE FOR B.B.C. MICRO

Title: HEREWARD THE REBEL
Subject: DANES AND NORMANS 1070
Age: 9+
Publisher: FERNLEAF
Source: EDUC. SOFTWARE FOR B.B.C. MICRO

Title: DOMESDAY DATABASE
Subject: GREAT BRITAIN 1986
Age: 7+
Publisher: BBC DOMESDAY PROJECT
Source: RESOURCE JUNE 1987

Title: HOW WE USED TO LIVE
Subject: 1874-87
Age: 8+
Publisher: IBA
Source: ITV ANNUAL PROG 87/88

Title: HOW WE USED TO LIVE
Subject: 1902-26
Age: 8+
Publisher: IBA
Source: ITV ANNUAL PROG 87/88

Title: HOW WE USED TO LIVE
Subject: 1936-1953
Age: 8+
Publisher: IBA
Source: ITV ANNUAL PROG 87/88

Title: HOW WE USED TO LIVE
Subject: 1954-70
Age: 8+
Publisher: IBA
Source: ITV ANNUAL PROG 87/88

Title: TIME TRAVELLERS' LONDON
Subject: HISTORY
Summary: A group of pupils select a period of history, and are presented with assignments to undertake.
Age: 9-14
Publisher: GSN EDUCATIONAL SOFTWARE 1986
Source: GSN EDUCATIONAL SOFTWARE, 50 STAMFORD STREET, ASHTON-UNDER-LYNE, LANCASHIRE. OL6 7LP. TEL: 061 339 6635
Cost: £25.00 + VAT

Title: TIME LINES
Subject: HISTORY
Summary: Complete British/World History Database
Age: 9-14
Publisher: SOFT-TEACH EDUCATIONAL 1987
Source: SOFT-TEACH EDUCATIONAL, FREEPOST, STURGESS FARMHOUSE, LONGBRIDGE DEVERILL, WARMINSTER, WILTS. BA12 9YB. TEL: 0985 40329
Cost: £21.00

Title: MYSELF
Subject: FIVE PROGRAMMES INCLUDING "PAST TO PRESENT"
Summary: Contains many illustrations of historical events, people, etc. A selection is presented for the child to place in chronological order.
Age: 8-13
Publisher: FIVE WAYS/HEINEMAN
Source: B.B.C. ED SOFTWARE DIRECTORY 87

Assessment Programmes

Title: PRACTICAL ASSESSMENT OF MATHEMATICS
Subject: MATHEMATICAL ASSESSMENT
Summary: A kit providing a comprehensive battery of 450 practical tests on tpoics including number, time, weight, length, volume, money, area, and shape.
Age: 7-12
Publisher: JORDANHILL COLLEGE
Source: SALES AND PUBLICATIONS, JORDANHILL COLLEGE, 76 SOUTHBRAE DRIVE, GLASGOW. G13 1PP. TEL: 041 950 3170/3171
Cost: £33.00

Programmes On Angles

Title: PRIMARY MATHS COURSE
Subject: LESSONS AND TESTS ON A VARIETY OF MATHEMATICAL TOPICS INCLUDING ANGLES
Age: 5-14
Publisher: LCL

Title: ANGLE
Subject: ANGLE
Age: 7-14
Publisher: CHALKSOFT LTD

Programmes On Fractions

Title: SHIPWRECK JUNIOR
Subject: FRACTIONS
Age: 6-11
Publisher: TOMSOFT

APPENDIX X: REVIEW OF SOFTWARE ON TIME

The following review was undertaken in order to investigate how, and to what extent, the important resource of computers is being used, and potentially could be used, to supplement more traditional types of work occuring in the classroom. In interviews, teachers and mathematics co-ordinators were asked about the use of computers to aid teaching of time. In addition programmes were evaluated to see how far short of the ideal they were. While this review is partly about time per se, it is also a critical consideration of primary software in general.

In fact, it transpired that there were very few programmes available on time in the schools involved in the study, so it was necessary to approach a number of other sources to gain access to them, including Durham LEA and Newcaste Polytechnic Microtechnology Centres. All Local Education Authorities have microtechnology centers which are provided to give teachers an opportunity to look at available software. It is assumed that the Durham Centre is a good representative example of the provision of this teaching resource throughout the country.

From the following examination of software it can be seen that there *are* useful and relevant programmes for teachers to use when teaching time. The software available on this topic at present can be broadly classified into two main groups. The first are drill and practice programmes, in which there may be more or less emphasis on either the teaching or the practice components, though both are usually present to some extent. Children are usually presented with questions about time, and may be given help if they are unable to answer them correctly. Progress is measured by score. The second are adventure programmes, in which time may be the major focus of the story, but more often is only an incidental part of what is covered. These tend to be based around a story, where the purpose may be to rescue prisoners, or help the main character achieve a task. The child must usually face a series of difficult situations which must be overcome.

Twenty five programmes directly on time were discovered, but only three of these were found in the six schools visited and only one had been used this year. Another sixteen programmes which indirectly covered time were found and none of these were used.

There were thirteen programmes which covered the topic of time indirectly, to varying degrees, though no doubt there is a wider range than this. One of these programmes was said to have been used. For the older children, a few programmes exist which cover the area of historical time, fifteen were found in this examination. Some software on related topics such as area and fractions was also seen.

Under the following headings are described some important factors relating to primary software, both in terms of what was found in the software examined, and what would seem to be advantageous. Some of the points may seem obvious but it is surprising how many programmes in fact do not fulfil these basic criteria.

The criteria that seem to be relevant in evaluation of software are numerous. The most important would seem to quality of feedback to both child and teacher, content of programme and facility to change this, and style of presentation of programme on the screen and in terms of both instruction, question, and response formats.

Short summaries of each of the programmes to be reviewed are presented first, to show the general form that programmes take.

X.1 Summary of the Programmes Reviewed

Four Funtime Programmes include a set of class demonstration clocks, both analogue and digital(24 hour), which seems a good idea, but they do move rather slowly, according to real time, although there is the facility to reset them to any desired time. Perhaps it would also be useful to have them move faster if required, so long as the teacher pointed out that real clocks do not move so fast. A teacher should also ensure that all children are satisfactorily able to see the screen.

There are also questions involving the reading of analogue and of digital time. Time is shown on a large clockface which fills most of the screen, and the child is asked to identify the time. When an analogue clock face is shown, there is a AM or PM in the top left-hand corner of the screen. There is an option to choose to answer in either 12 or 24 hour digital form.

Mathemagic Land is really just a set of sixteen maths problems, made more interesting with a story. By answering them correctly, players can win eggs to enable them to rescue prisoners.

In **Timetables**, the first screen describes an appointment and its time, it displays a 24 hour bus timetable with 4 bus times, an analogue clockface set at the time of the appointment, a large analogue clock and a small digital display of the time, and a message, eg. "it's a 5 minute walk to the bus stop. Which bus should Lenny catch?". The child must choose a bus time, 1-4, and then press the space bar to start the analogue and digital clocks, and then press it again when he wants Lenny to run out of his house to the bus stop. When the next bus comes along, it picks him up. The bus comes along at the timetabled times as the analogue and digial clocks reach those times. Thus the child must read the timetable to decide which bus Lenny should take, and use the moving clock to decide when he should leave home to catch that bus. Situations increase in difficulty, but there are a set number of appointments which do not vary so the number of times the programme can be used is restricted.

For **Feeding Time** the child is provided with a feeding timetable and an analogue clock. He must mark the next feed due on the timetable, make Petra collect the appropriate food and feed it to the correct anaimals. The skills required involve reading time, matching time on the timetable to the clock, reading the animal name, finding the route along the maze of paths to the food stores and then to animal houses. It is quite a basic programme, more concerned with matching rather than identification of time. All times are on the hour, half hour, or quarter hours only, and they are not written out in words.

The Wizard's Revenge is an adventure programme with a series of problems and logical thinking situations on a number of topics. Part of the way through the programme, the child finds himself in a desert. A bus timetable from the desert to the castle and a large analogue clock are provided. There are two buses, one leaves desert at 3:00 and arrives at the castle at 4:00, and the other leaves at 4:30 and arrives at 5:30. The child is told the time is 1:00 and asked how long before the first bus leaves the desert, and how long a bus takes to travel to the castle. He must fill the answers in to the format " _ hours". Then the child is asked to move the hands on the clock (by pressing the key F for forwards and B for backwards) to the departure time of the first bus. He is reminded that bus 1 leaves at 3:00. As the hands move there is a "tick, tock" sound. When the clock says the correct time, the bus moves off through the desert.

Time Puzzles involves practice in telling time by sorting clocks into sequential order. The top line of the screen is filled with 5 spaces, which fill up one at a time as each set of 5 questions are answered correctly. Below this are 4 clocks at different times, with the hour hand in red and the minute hand in blue. The left-hand clock has a box around it. Below these clocks are one clock with the words "time now" below it, and 4 empty boxes. It is not clear what must be done. The child is told to press the spacebar to check the next clock. The child must mark the clocks in sequence, starting with the one set at the time which follows the "time now". The procedure continues until all the clocks are marked.

Time Journey involves the working out of time periods elapsed using a simple time scale. On the first screen is a line a-b-c-d-e, with equidistant points, b and e are in red. The distance a-b is labelled "60 minutes". Below the line is a key... a) is the railway station, b) is the post office, etc. Below the key are 5 analogue clocks, all at 6 o'clock. The left-hand clock is red and labelled "starting time". Below this is the instruction "The journey is Post Office to School". The children have to set the second clock to the finishing time of the journey. After this another journey is displayed and the rest of the screen stays the same. If half hours are selected, distances between points are all half an hour except one journey of an hour. The clocks move in half hour jumps when adjusted. If quarter hours are selected, one distance is a quarter hour journey and the rest are half hour journeys, and the clocks move in quarter hour jumps.

Two players are required to use **Before and After**. The hands on a large analogue clock move accompanied by a "pip, pip" noise. Then the first player is asked eg. what the time will be in 35 minutes, or what the time was 10 minutes ago. Then the same player is asked what the time is now. Then it is the turn of the other player. Thus children must tell the time at five minute intervals, find times that are a given number of minutes earlier or later than a stated time, and relate written times to both digital and analogue displays.

Town is a simulation of a journey from home to town to meet some friends. The player has a fixed sum of money and has arranged to meet friends at a set time. On the way there are a number of incidents which require a reaction. For example, the player reaches the bus stop and is told the fare is 20p. He is given the option of catching the bus or walking on. Sometimes there are as many as 4 or 5 options. The player can respond in either words (the words "catch" and "walk" are highlighted), or numbers (option 1 or 2).

In **Time Flies** there are either two players who play against each other, or one player who competes with the computer. The player is told that his oppontent is choosing a number between 1 and 30. Two lamps fill the screen, one belongs to each player. The first player's lamp goes on and a jar beneath it is filled with squiggles as music is played, then it stops. A small hand on a clock on the screen moves when the light is on and shows the number of seconds the light was on for. Only the 0,15,30,45 second points are marked. The second player has to guess how many seconds the light was on for. Then the roles are reversed.

Wrecker's Rock is an adventure which gives experience in decision making, problem solving and research skills. It begins when a conversation is overheard between two men who are planning to attack a lighthouse, smash the light and so wreck a ship. The story proceeds by detective work by the player(s). The research skills required include reading bus timetables. There are two 24 hour bus timetables. Both have five stops, one set of times is shown for each, but after that the player is simply told that buses come "every half hour until", a last set of times. The child must choose the correct bus. He is told he is outside the Grand Hotel and the time is 13:50, and asked what time the next bus comes. He must remember where he is starting from and calculate the time of the bus, as it is not directly displayed on the timetable.

The BBC Microcomputer Disc System programme **Clock** has three different clock displays - an analogue display clock, a digital display clock, and an analogue and digital display. All clocks show hours, minutes and seconds. They begin at 00:00:00 when the programme is entered and move according to real time. There is a facility to reset the time.

X.2 Feedback and Reinforcement to the Child

Feedback should make sense and happenings should have realistic and comprehensible outcomes. Timetables is good at this, for example it gives the message "Lenny's friends have gone" if Lenny arrives late. Also in Feeding Time if the player tries to feed the wrong food to some animals, the keeper appears and tells him that the eg. snakes don't like that food.

The provision of visual, and sometimes also auditory, rewards is common. However the biggest failing is that they are rather feeble, so are disappointing. For example, in Wrecker's Rock the police simply take the crooks away. In Feeding Time, the player sees the animals eating and saying "yum yum", but this is rather boring. Town has quite effective rewards, for example when the player reaches town, if he and his friends choose to go to the disco, flashing lights are shown. Timetables could provide a greater visual reward when a task is performed correctly, for example, if the player helps Lenny get to the cinema on time, he could see what happens inside.

A variety of methods operate to show a pupil whether he has answered a question correctly or incorrectly. Some simply tell the child the accuracy of his response through a message such as "Well done, you have got it right", as in Time Puzzles, or "Wrong" as in Before and After. Other programmes provide more stimulating feedback. In Four Funtime programmes, for example, if the child answers a question correctly, the hands on the analogue clock face change to a smiling mouth, and eyes and nose are added, and the message "Well done" appears along with a musical jingle. On the other hand if the answer given was incorrect, the hands change to a sad mouth, eyes and nose are added, and the message "Try again please" is given.

If a question is answered incorrectly, a child tends to be disappointed if he is not given another try at getting it correct. Programmes are quite good at providing a second chance, but some take this too far, continuing to give the child another go at providing the correct answer, after every incorrect one. In this case if a child really does not know the answer and cannot get it by chance, he will need some help to progress further in the programme.

Four Funtime Programmes, for example, just keeps on saying "try again" until the correct answer is entered. Estimation Programs purposely makes the programmes infinitely patient so as not to put the child under pressure. The child is given as much time as he requires to make an estimate and allowed as many tries as are necessary. Since sooner or later the child will get the correct answer by chance, this is not too much of a problem. A good feature of this programme is that although the number of attempts is reported on the screen, once a new question is begun, the details are forgotten. Feeding Time also follows a policy that the child can't fail. Although it does not tell the child if he has marked the wrong feed, it does tell him when he attempts to feed the wrong animal that it is not yet time for it to be fed.

What is needed, is a help facility, and some programmes do provide this. In Mathemagic Land, for example, the child can call the Wizard three times to recieve help. In Before and After, if there is no response from the child after 25 seconds, the computer prompts by counting round the clock in minutes (either backwards or forwards), signalled by pips, and at each 5 minute mark places an asterix to aid an answer before the time runs out. When the correct point on the clock has been reached, if an answer has not been forthcoming, the child is given the message "out of time".

After a help facility, if this has failed to produce the correct answer, a feedback loop is required, again some programmes do attend to this. In Timetables for example, after two wrong attempts, the remedial loop operates, the child is told if he chose the wrong bus, the correct bus is highlighted, and the analogue clock is shaded to show walking and travelling time. If the answer is still incorrect, the sequence is demonstrated.

Scoring is not always straight forward, in both Time Puzzles and Time Journey for example, when five questions have been answered correctly, the message "Well done, you have answered one problem correctly" appears, and one empty space is coloured in. This is a bit of a disappointment.

The scoring in Before and After seems much more comprehensible. The player is given two points (in the form of pictures of clocks) for a correct answer, and one point if help was recieved. At the end of the game the scores of the two players are compared and a message congratulating the winning player and telling him what his score was, is given. This may be a bit demoralising for a child if he keeps losing, but on the other hand, it could argued that competition is a good thing.

Some programmes tend to forget poor scores once a problem has been completed sucessfully which is probably a good policy to adopt for young cildren, from the point of encouragement.

In adventure games it is sometimes arbitary as to which answer is correct, and this may be confusing to children. Programmes should guard against being incomprehensible, so that a child is unable to benefit from his mistakes. There are cases where there is no way a child could have known that a left or right turn would lead to a dead end and it is quite reasonable and realistic that a child should have to turn back. However what often happens is that the child is sent back to the beginning of the programme so that all of his previous work is lost. Because of the nature of computer use in the classroom, this is usually the point at which the child must leave the computer, so this turn of events can be very frustrating, especially if no satisfying explanation of why it occurred, is recieved.

In conclusion, various points seem to be important with regard to the supply of information to the child, regarding his progress. Feedback should be immediate so that it can be related to the question concerned. Drill and practice questions should have some meaningful score hierarchy, so children see themselves progressing. And a *satisfying* reward (auditory and visual) should be recieved, rather than something silly. Feedback loops are necessary in which the child gets 1 or 2 chances and then is told (and perhaps repeats) the answer.

X.3 Feedback to the Teacher

There did not appear to be a great deal of information storage as feedback for the teacher. Some programmes do give feedback to the teacher and child during a particular session eg. Four Funtime programmes, but few retain the information for a whole class at once so that the teacher can review the progress of her pupils later on. It was quite common for children to type in their names at the beginning of their go so that the programme could communicate to them by name. It would be just a small, but important step for the programme to record these names with the corresponding score, for the teacher to peruse at her leisure. In this way teachers would be able to begin to monitor progress and attainment. Of course information about level reached and score attained is really only the beginning of what is needed, it would be ideal if programmes could diagnose the difficulties of individual children.

If this information was made available to the teacher, she would be in a position to use supplementary teaching, or even programmes to the best adavantage to help programmes which help certain understandings mature in particular children.

X.4 Options

Programmes are quite good at providing a variety of options. Sound and difficulty level are the most common options provided, but response method, question type, instruction format, and number of players, can also be encountered. The ability to vary sound level has obvious advantages since classrooms differ widely in the amount of sound which they can accommodate. Wrecker's Rock and Time Puzzles are two programmes which have this option.

With regard to difficulty levels, some programmes simply have easy and hard options, such as Time Flies, others have a much wider selection of possibilities, eg. Four Funtime Programmes have nine difficulty levels, ranging from the precision of questions on the o'clock, to questions on all times.

The provision of a choice of difficulty levels is worthwhile as it allows the teacher to adjust the level of the programme to that of her class, so that only those aspects of time that have been taught are covered. Thus the programme reinforces and tests what the child knows, but does little to increase his learning, unless a teacher sets it to do so. An additional facility which allows teachers to set their own requirements, would be particularly useful, as work taking place in clasrooms can vary emmensely.

The opportunity to select question type can also be provided. Four Funtime Programmes for example, allow selection between setting the clock hands on an analogue clock or on a digital clock, or looking at an analogue or a digital demonstration clock. In Time Puzzles there is a simple choice between sorting clocks or going on a time journey, and if the former is chosen, there is a further choice between 12 and 24 hour digit answers.

Four Funtime Programmes gives a choice between written and numerical instructions. In terms of response method, Town gives two optios, either typing keywords or using numbers. Time Flies allows either two players to play against each other or one player to take on the computer.

X.5 Instructions

Good simple instructions are vital, especially when they must be understood by an immature audience. Four Funtime Programmes and Town are both precise and succinct. The former gives clear instructions to press M to move the minute hand and press H to move hour hand. Surprisingly some programmes do not mention that this is the way to respond. Town gives imnportant information in a clear form, "It is 3pm. You are going from home to meet some friends at 4pm in town. You have £1.00 to spend."

Some instructions have no other fault than simply being long and complicated and therefore not always suitable for their intended audience. Teachers quite often mentioned this fault in discussions during this study. Children vary greatly in their reading ability, so that some are unable to cope with such demands. Both Mathemagic Land and Timetables are guilty of this fault.

The most serious problem with instructions is that in many cases it is not at all clear what to do, eg. Time Puzzles gives no instructions as to how to achieve the desired goals, or any explanation of all the information on the screen. the child would need to be told what to do. In Feeding Time, it is not clear that Petra is on a path and that she can go left and right as well as up. Nor is it clear how to mark the feed, and it doesn't tell you if you have marked the wrong feed, so that much time is wasted until you find this out later on.

Time Journey involves a complicated system of setting clocks to show the arrival time, having calculated a journey's length and added this to a clock set at the starting time. After setting the clock and pressing space bar, the clock turns red and the remaining clocks in a row change to this new starting time. However nowhere is the procedure explained.

Thus Instructions *must be clear* for the smooth running of the programme and to enable children to gain the most from their involvement with it. Instructions could also be displayed in a booklet but children should be able to progress through the program with the instructions on the screen only, though these should not be too repetitious. From reading and responding to instructions children should be able to see the point of what they are doing, understand what is required, how to respond and in what form the response is accepted, the teacher or another child should not be required to explain the system.

X.6 Questions - Random/Changing

If a programme is designed to be followed through only once, then there is no need for questions to vary each time the programme is followed, but if a programme is designed to be used repeatedly by the same child, the questions must be designed in such a way as to avoid a child remembering the answer from previous exposure to the programme or becoming bored. The Wizard's Revenge is good as the questions change each time the adventure is followed. But in Town there do not seem to be very many variations of possible happenings at each point in the route, eg. on the bus there are only two possible situations, so there is probably a rather low limit to the number of times the game can be played by the same child. Wrecker's Rock can only really be worked through once as the questions and answers are fixed and do not vary at all.

X.7 Pre-requisites

It is very important that teachers are fully aware of the required pre-requisites for each programme, so that they ensure that their pupils will not be asked questions beyond their knowledge, which could lead to discouragement. Age range suitable is usually specified and this is helpful, but clearly the pre-requisites also need to be declared. clearly stated either in a clear position at the beginning of the accompanying booklet or even on the disc itself. guide, rather than simply age.

Some programmes require participants to read an introductory booklet before using the computer, this may be in the form of a story as in The Wizard's Revenge. In such cases, it must be ensured that children have sufficient reading skills to cope with this, or are given help if they do not.

For Programmes with timetables participants must understand the 24 hour clock, eg. Timetables. The option of the use of the 12 hour clock would enable such programmes to be used by younger children also, as for example in the Wizard's Revenge.

X.8 Time

The time a programme takes to complete is not a matter of major concern. However the situations in which it is likely to be used should be bourn in mind. For example it is usual, particularly with drill and practice and question/answer type programmes, that children will have a turn at the computer for a short period of perhaps up to ten minutes, whereas a child may have twice this period for an adventure programme, often being allowed to continue until he either finishes or fails in his quest. In both cases the child's time on the computer will not usually be sufficient to work right through the programme, and the lapse of time before the next turn is likely to be considerable. This should be taken into consideration when designing such programmes.

It would be advantageous if programmes of both types allowed children to skip some of the earlier work covered to avoid unnecessary repetition when returning to a programme, though of course some repetition is a good thing to reorient the child to the work. Some programmes already do this, usually through the use of a password (though children do not always remember them) in adventures and through options of question type in question/answer programmes.

X.9 A Discernable Purpose

The Four Funtime Programmes are all very much the same. They are very repetitive and rather boring. Although they are question-answer format, they could be a lot more exciting. Timetables is also a question-answer programme, has a clearly designed point to answering the questions. The child must strive to help Lenny who is always late, get to appointments on time. Time Flies surprisingly only has one task, and it becomes boring having to repeat the same thing all the time. Also it is difficult to see why there are jars which fill up. There must be more interesting ways of dealing with the estimation of time.

Many programmes have a story line and this can help to add interest. Wrecker's Rock uses a story as a base but it is not particularly exciting. Some programmes concentrate on being realistic but still maintain interest. If outcomes are realistic, children can understand what is happening and have some chance of predicting what will occur, eg. in Town, it is only possible to meet friends close to 4 o'clock and the amount of money remaining determines the activities possible after having met them. Timetables, because of its good connection between the skills being tested and real situations, is easy to see the point of.

Adventure games tend to have clearly defined purposes. In the Wizard's Revenge, for example, the purpose is to rescue the Dragon King who has been imprisoned by the wicked wizard.

Children, though not perhaps aware of the full educational implications of what they are doing, should still be aware of the short term goals of the program eg. to score high or progress through an adventure, as well as have some idea of how they will benefit.

X.10 Format of the Question and Answer

Children are often more familiar with one way of expressing time than others, so it is very important that the way the questions are worded fits in with the way the child is used to thinking about time. Similarly, the form in which the answers are required should be compatible with children's knowledge and understanding. It is a major failing of a number of programmes that pupils can easily input the correct answer but get the question wrong because they have not given the answer in the right format. Thus they are mislead into thinking that their answer was incorrect. The question should emphasise in which format the answer is required. The use of markers such as a colon for digital answers would be useful so that the child knows what is required and where to put the answer. This does have the disadvantage of not being able to test knowledge that a digital answer requires a colon, but the benefits of clarity should outweigh this. Four Funtime Pogrammes for example, required a written form of the answer eg. "20 to 4", not "3:40", and for digital answers, letters are not accepted.

Before and After confines questions and answers to "minutes to" and "minutes past" only, which makes it suitable only for children who have been taught in this manner. Children are asked for their answer by a prompt of "- minutes to --", or "-- minutes past -".

Perhaps question and answer format should be an option for the teacher, because it must be compatible with the way a particular class of children have been taught.

X.11 Screen Presentation

The screen can sometimes be too crowded. Timetables suffers from this problem. The screen is too crowded so that it is difficult to see the digital time squashed in corner, and the analogue clock and hands, because they have to be small to allow space for all the other things on the screen, have a rather rough shape. All minute marks are the same, the five minute marks are not highlighted or bigger than the other minute marks, therefore sometimes difficult to see where the hand is actually pointing. There is perhaps just too much information to take in at once, it all seems to merge together.

The screen should be clear and easy to read, with space for instructions, questions and answers, so all can be interrelated. It should be colourful, but not overstimulating and therefore overwhelming. Before and After does this well. There is a large analogue clock on one side of the screen and a digital display beneath it, both saying the same time. On the other side of the screen the question is presented and there is space for the answer. At the bottom of the screen, the score of players one and two is displayed. Town uses only one line at the bottom of the screen which continually keeps the player aware of the status of the remaining time and money.

X.12 Special Effects: Graphics and Sounds

There are some very effective graphics, both varied and stimulating, such as those in The Wizard's Revenge, which in addition present realistic noises of the sea, birds, and Auntie snoring! Timetables shows a good sequence of Lenny running out of house and getting the bus.

Other programmes, like Town and Wrecker's Rock have very basic graphics. This does not in itself necessarily detract from the educational value of the programme, so long as children are able to correctly interpret what is being displayed, but good graphics have a greater chance of stimulating and keeping interest.

Thus graphics should be good approximations to what they represent, interesting, and stimulating. This is especially the case for rewards which are often in the form of some graphical and sound combination. However these are often disappointing. Perhaps children could recieve a little 20 or 30 second scenario for sucessful completion of a programme or section of a programme, for example in Timetables, when Lenny sucessfully meets his friends at the cinema, it would be satisfying to see them go inside and see what happens.

X.13 Extra Resources

Additional resources provided with software can include games, worksheets, word processors, books, posters, etc. Examples of well resourced packs include Wrecker's Rock, and Zoopak which has extensive project-based materials.

Supplementary material can greatly increase the educational value of computer programmes. It allows a class topic to be developed around the theme of the programme, so has considerable benefits to the teacher. However, all programmes should also be self sufficient, so that the teacher is able to use them alone to complement what is already ongoing in the classroom.

X.14 Conclusion

Thus it can be seen that the quality of primary software on time tends to be poor, since the criteria considered to be important factors in the design of programmes are in many cases not adequately fulfilled. Most programmes have satisfactory features in some domains, but fail in others. The ideal approach would seem to be the production of programmes which combine the best features of all those currently available.

However, more than this is required. The ways in which children learn about time must be clarified, so that this information can be used to construct computer-based material that best fits children's learning patterns.

REFERENCES

Ames, L. B. (1946) The Development of the Sense of Time in the Young Child. Journal Press, Princeton, Mass., and Journal of Genetic Psychology, 68, 97-125.

Attisha, M. & Yasdani, M. (1983) A Microcomputer Based Tutor for Teaching Arithmetic Skills. Instructional Science, 12, 4, 333-342.

Bachrach, B. (1973) No Time on Their Hands. Arithmetic Teacher, 20, 102-108.

Barcott, R. A. (1973) Time-Telling in Special Education Classes. Education and Training of the Mentally Retarded, 8, Dec, 207-211.

Benoit, P. E. & Valeno R. S. (1962) Teaching Retarded Children to Tell Time. Training School Bulletin, 59, 22-26.

Britton, R. (1981) Teaching how to Tell Time. Academic Therapy, 16, 409-413.

Burton, G. & Edge, D. (1985) Helping Children Develop a Concept of Time. School Science and Mathematics, 85, 2, 109-120.

DeLoach, R.H. (1982) The Little Hand Tells You When. Arithmetic Teacher, 30, 2, 39-40.

Hofmeister, A. & Lefevre, D. (1977) Time is of the Essence. Teaching Exceptional Children, 9, 82-83.

Horak, V.M. & Horak, W.J. (1983) Lets do it: Teaching Time with Slit Clocks. Arithmetic Teacher, 30, 5, 8-12.

Jeffers, V. (1979) Using the Digital Clock to Teach the Telling of Time. Arithmetic Teacher, 26, 7, 53.

Karmiloff-Smith, A. & Inhelder, B. (1975) If You Want To Get Ahead, Get a Theory. Cognition, 3, 3, 195-212.

Krustchinsky, R. & Larner, N. (1988) It's About Time. Teaching Exceptional Children, Spring, 40-41.

Lipstreu, B.L. & Johnson, M.K. (1988) Teaching Time Using The Whole Clock Method. Teaching Exceptional Children, 20, Spring, 10-12.

Lovell, K. & Slater, A. (1960) The Growth of the Concept of Time: A Comparative Study. Journal of Child Psychology and Psychiatry, 1, 179-190.

Lumb, D. & Papendick, A. (1978) Mathematics 5-9. Murray.

Maertens, N. (1980) Using an Hour Clock to Teach Time. Arithmetic Teacher, 27, 7, 38-39.

McIntyre, M. (1975) Is it Time Yet? Science and Children, 12, Mar., 38.

Muto, T. (1982) The Structure of "Life-Time" in Young Children. Japanese Journal of Educational Psychology, 30, 3, Sept, 185-191.

Nelson, G. (1982) Teaching Time-Telling. Arithmetic Teacher, 29, 31-34.

Nelson, K. (1986) Event Knowledge: Structure and Function in Development. New Jersey: Lawrence Erlbaum Associates Inc.

Nibbelink, H. W. & Witzenberg, H. G. (1981) A Comparison of Two Methods for Teaching Younger Children to Tell Time. School Science and Maths, 81, 429-435.

Partington, J. W., Sundberg, L. M., Iwata, B. A. & Mountjoy, P. T. (1979) A Task-Analysis Approach to Time Telling Instruction for Noramal and Educably Retarded Children. Education and Treatment of Children, 2, 17-29.

Peterson, D. (1973) Functional Mathematics for the Mentally Retarded. Columbus, Ohio: Charles E. Merrill Publishing Co.

Piaget, J. (1946) Le Developpement de la Notion de Temps Chez L'Enfant. Paris: Presses Univer. France.

Reisman, F. K. (1971) Children's Errors in Telling Time and a Recommended Teaching Sequence. Arithmetic Teacher, Dec, 1976, 582-591.

Reisman, F. K. & Kaufman, S. H. (1980) Teaching Mathematics to Children with Special Needs. Ohio: Merrill.

Riley, J. E. (1980) It's About Time. The Arithmetic Teacher, 28, 2, 12-14.

Schechter, D. W., Symonds, M. and Bernstein, F. (1955) Development of the Concepts of Time in Children. Journal of Nervous and Mental Disease, 121, 4, Apr., 301-310.

Schultz, K. (1979) Linear Clocks. Arithmetic Teacher, 26, 7, 40-41.

Springer, D (1951) Development of Concepts Related to the Clock as Shown in Young Children's Drawings. Journal of Genetic Psychology, 79, 47-54.

Springer, D. (1952) Development in Young Children of an Understanding of Time and the Clock. Journal of Genetic Psychology, 80, 83-96.

Strangman, K. B. (1972) The Sands of Time - A Sandglass Approach to Telling Time. Arithmetic Teacher, 19, 123-125.

Thompson, C. S. & Van de Walle, J. (1981) A Single-Handed Approach to Telling Time. Arithmetic Teacher, 28, 8, 4-9.