CHAPTER 6 - DESIGN OF FRACTIONS AND TIME MANIPULATIVES

6.1 DESIGN AND CONSTRUCTION OF MANIPULATIVES

As a result of this investigation an attempt was made to design improved concrete materials or manipulatives for use in the teaching of Time and Fractions and to devise recommendations for their appropriate use. Two kits of manipulatives were designed for this purpose. These were named the FIT KIT (Fractions In Time Kit) and the CUTE KIT (Children Understanding Time Educational Kit). The aim was to design materials that fulfilled the following specifications:-

* The materials should be appropriate and effective aids in remediation of children with learning difficulties in regular classrooms.
* The materials should be useful in teaching children of all abilities found in regular classrooms.
* The materials should be applicable to whole class, small group and individual instruction.
* The materials should be open-ended and lead to problem posing and creative problem solving.
* The materials should provide opportunities for extension of more able students.
* The materials should stimulate concept development, as well as language and acquisition of symbolic

representations in learners.

* The material should be suitable for use at the concrete stage as well as the bridging stage of mathematical learning.

* The materials should have common elements with symbolic representations of Time and Fraction problems.

* The materials should have common elements with real-life situations in which Time and/or Fraction mathematics can be applied.

* The FIT KIT materials should make connections between the mathematical topics of Fractions and Time.

* The CUTE KIT materials should make connections between digital time calculations and base ten 4-digit addition and subtraction operations.

* The materials should be related closely to the aims and objectives of the N.S.W. Mathematics K-6 Syllabus.

* The materials should comply with Australian and overseas research recommendations for effective mathematics manipulatives.

* The materials should complement everyday and existing materials.

* The materials should be durable.

* The materials should be aesthetically and kinaesthetically pleasing.

6.2 THE FIT KIT

The FIT KIT consisted of:

1 base board

2 reversible outer rings

1 full circle

2 half circles

4 quarter circles

12 twelfth segments

1 stand

1 perspex clockface with detachable hands

3 sets of teacher-made question cards

Set A: whole class

Set B: remediation

Set C: extension

Progress record cards

Answer cards

Assessment tasks

Answer booklet

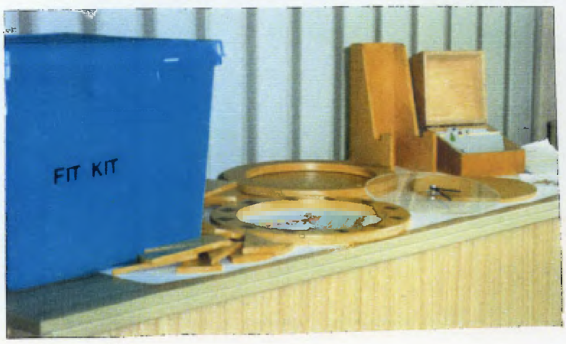
Teacher's assessment and evaluation chart

Children's evaluation forms

(See Appendix IV)

The FIT KIT was designed to develop the concept of Fractions as parts of a whole. It was not designed to apply to tenths or hundredths since (i) MAB Blocks are widely used and effectively fulfil this need and (ii) these fractions are not generally related to Time language or calculations.

PHOTOGRAPHS 6.1 - THE FIT KIT IN USE



The FIT KIT was designed to be appropriate for use by children from Years 1-6. The kit relates to the N.S.W.Mathematics K-6 Level 1 Fractions Objective 3 (that children should be able to "manipulate concrete materials to show a part of a whole" and "name a part of a group and the parts remaining") and the Level 3 Fraction Objective 11 (that children should be able to "write fractions in the form a/b") (1989,175,262). The Level 2 Fractions and Decimals Objectives 4-10 deal almost exclusively with tenths and hundredths. Fractions are not emphasised except in their relationship to 2-digit decimal numbers in these objectives which are recommended for Years 2-4 (Mathematics K-6, 1989, 262). It is not made clear in the document that consolidation and revision of pupils' knowledge of fractions must continue to occur during mathematics lessons during Years 2- 4 for progress to occur in later years.

The use of calculators and the metric measuring system in Australia are underlying reasons for the strong emphasis on decimals. In countries where the metric system is not used general fractions are considered more relevant and useful.

However, the main reference to fractions in everyday life for most people is in relation to telling the time. We still use fraction language regularly in this way (eg.

half past; quarter to; quarter past; in half an hour). This is the case despite the movement towards digital timepieces. The N.S.W. Syllabus Level 2 Time Objectives 10 - 14 stress the use of both digital and analog clocks and their associated language (1989, 175). Thus, it is necessary for children to combine mathematical knowledge of Fractions and of Time to fully understand telling the time using analog clocks.

The FIT KIT can be used for teaching fractions and time separately and then helping children to make the connections or for teaching fractions and time simultaneously. The teacher can start learners from wherever they have the strongest mathematical concepts and help them to construct their new learning upon that base.

In the FIT KIT each fraction segment is marked on one side only with the appropriate mathematical fraction symbols. This means that the symbols can be introduced when the teacher deems appropriate or when the learner notices them and shows an interest. It also provides opportunities for extension for more able students into equivalent fractions (2/4 = 1/2), operations on fractions (1/4 + 1/4 = 1/2; 1/2 - 1/4 = 1/4) and mixed fractions (1 +[2x1/2] +1/4 = 2 1/4). The FIT KIT is open-ended in this way deliberately to encourage creative mathematical problem solving in more able students.

At the same time the FIT KIT was designed to assist children having learning difficulties in mathematics by providing visual and kinaesthetic experiences with parts of a whole that can be manipulated side-by-side or stacked or fitted into the base like a puzzle. The FIT KIT lends itself to small group work or one-to-one instruction which is necessary for such learners to develop, consolidate and retain concepts and language often rapidly mastered by their more able peers (Baker, Young & Martin, 1990). The relationship of these fractions to the clockface can be made once the fraction concepts are mastered.

The FIT KIT was constructed from craftwood so as to be strong and hard-wearing. The pieces were finished as polished natural wood and were pleasant to look at and touch. This simple construction also facilitated the use of the materials in real-life connecting activities such as sharing them out as slices of cake or pizza.

The fraction segments were not coloured different colours for different sizes as is the case in almost all commercially available fraction circle sets. This was because it was decided that the introduction of a colour factor would distract from the size concepts which the material was designed to display. Children with learning difficulties in mathematics are more likely to be confused by such unnecessary distractors and gain erroneous concepts such as "two reds are the same as a blue" (if quarters are red and halves are blue) which is not useful in terms of building mathematical structures and symbol use.

This kit could be used alone, in association with other everyday or commercially available materials or with the CUTE KIT. Thus, the FIT KIT was considered to fulfil all the specifications previously outlined for the design of effective mathematical manipulatives.

6.3 THE CUTE KIT

The CUTE KIT consisted of :

2 sandtimers

A minute timer

A stopwatch

An alarm clock

An analog clock

A digital clock

A teaching clockface

A set of cardboard clockfaces

A set of digital clock faces with pull through number strips

A set of clockface stamps

A stamp pad

A set of calendar sheets

3 wooden digital clock models

A set of magnetic digits and dots

3 sets of teacher-made question cards

Set A : whole class

Set B : remediation

Set C : extension

Progress record cards

Answer cards

Assessment tasks

Answer booklets

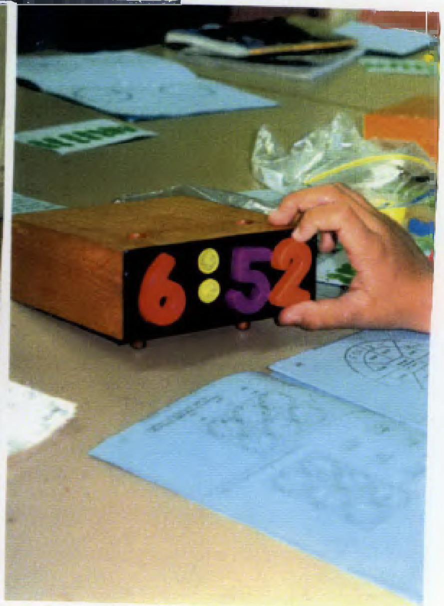
Teacher's assessment and evaluation chart

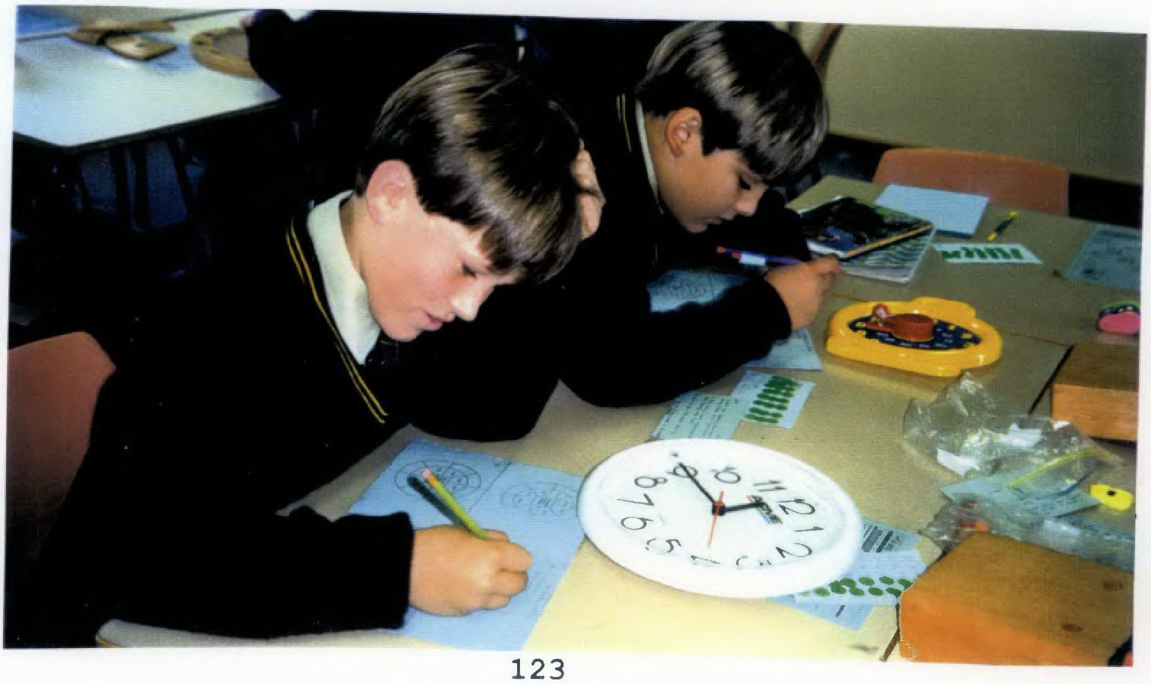
Children's evaluation forms

(See Appendix V)

The CUTE KIT was designed to develop concepts of time starting from informal, personal experiences of units of time through to using symbolic representations of time with fluency and accuracy. The kit consisted of a mixture of everyday, teacher-made and commercially available equipment.

PHOTOGRAPHS 6.2 - THE CUTE KIT IN USE





The CUTE KIT attempted to provide for a range of learning experiences appropriate to the concrete, bridging and symbolic stages of mathematical development in relation to Time. Its focus was to strongly connect for learners their experiences of the duration of different units of time with their skills in time telling using analog and digital clocks.

The kit was also designed to provide strong common elements between real life and the manipulatives and between the manipulatives and time symbols. For this reason the FIT KIT was considered an excellent additional teaching tool since the perspex clockface was designed to have removable hands which would allow for the introduction of one hand at a time to prevent the common confusion between hands when they are perceived visually with insufficient meaning attached to their respective purposes (Smith,1987).

The range of instructional activities provided in the sets of question cards were adapted from the Resource Materials for Basic Learning K-6 Mathematics support documents for the N.S.W. Mathematics Syllabus (1989). They related directly to the aims and objectives of the Syllabus for Time Level 2, as well as revising some Level 1 objectives and extending into early Level 3 objectives. The questions were developed to use effectively the manipulatives in the CUTE KIT to assist all children in regular, mixed ability classes in the Lower Primary to "construct mathematical understandings by playing games, manipulating concrete materials, investigating problems related to personal experiences and discussing ideas" (Burk, 1992).

It was assumed that children with learning difficulties in mathematics would take longer to work through those activities appropriate to them and would require teacher assistance in small group work and individual instruction. For this reason extension cards requiring higher order thinking skills, creative problem solving and application of understanding were included in the kit as Set C. It was envisaged that more able students who had completed Set A and did not require remediation or consolidation from Set B could extend and apply the basic skills they had mastered using Set C independently while the teacher assisted those children in need of remediation.

The model digital clocks with magnetic numbers and dots were designed as a connection between real digital clocks and symbolic representations of them. No such material was currently commercially available. Activities such as matching the real clock were devised so that learners could manipulate the digits and dots with careful observation and attention to detail. Thereby, the concepts of the place value of minutes and hours could be developed or consolidated.

For the more able students comparisons to base ten 4 digit numbers could also be explored using the digital clock models. With this purpose in mind the models were constructed with two holes on the top and two cylindrical pegs on the bottom so that they could be stacked three high. When used this way they provided common elements to the symbolic representation of multiple digit addition and subtraction. It was envisaged that the same apparatus could be used in developing multiple digit addition and subtraction algorithms at a later date with the inclusion of magnetic strips to form equal signs and Hundreds, Tens and Units magnetic characters to reinforce place value.

The CUTE KIT was considered to comply closely with the original specifications outlined for the construction of effective mathematical manipulatives.

6.4 ASSESSMENT TASKS

A series of 15 parallel assessment tools or probes based on the N.S.W. Mathematics K-6 Level 2 Syllabus Objectives for Fractions and Time was formulated. Each probe consisted of the following items:

FRACTIONS

* Name the parts of the whole fraction coloured.

* Colour the parts of a whole fraction.

* Name or colour the parts of a fraction of a group.

* Colour the named fraction of a clockface.

* Colour the hundredths expressed numerically.

* Colour the hundredths expressed in words.

* Write the hundredths fraction shaded.

TIME

* Write or show the analog time.

* Write or show the digital time.

* Convert digital to analog time.

* Convert analog to digital time.

* Put hands on clockfaces to show - o'clock, half past, quarter past, time to multiples of 10 minutes, time to multiples of five minutes, time to multiples of one minute - from words and digital displays.

The Fractions items on the parallel probes covered the Syllabus Objectives for Fractions and Decimals 3,4 5 and 6 which are those suggested as appropriate for Years 2 and 3 and which are covered in the Year 3 textbooks. The Time items on the parallel probes covered the Syllabus Objectives for Time 9, 10 and 11 which are those suggested for Years 2 and 3 and which are also covered in the Year 3 Textbooks.

Assessment items were adapted from the Syllabus or from photocopiable assessment tasks provided for teacher use in the teacher handbooks of the most preferred Year 3 Mathematics textbooks. The same layout and format was used for all probes with numerical substitutions being made to formulate equivalent items.

CHAPTER 7 - TRIALING OF THE MANIPULATIVES

7.1 RESEARCH DESIGN OF THE TRIALING OF THE MANIPULATIVES

The FIT KIT and the CUTE KIT were designed in accordance with current research recommendations relating to effective mathematical manipulatives.The associated learning activities and assessment items were derived from the N.S.W. Mathematics K-6 Syllabus (1989) and adapted from the top four teacher-preferred mathematics textbooks for Year 3 as ranked in the Upper Hunter survey reported in Chapter 4. These materials were designed in an attempt to deal specifically with the teaching of Fractions and Time to children with learning difficulties in mathematics in the regular mixed-ability classroom. The next step was to put the newly designed learning materials into use and to evaluate their usefulness.

Leedy (1993, 139) states "All research methodology rests upon a bedrock axiom: The nature of the data and the problem for research dictate the research methodology...If the data is verbal, the methodology is qualitative, if it is numerical, the methodology is quantitative." This cool, objective statement reduces the lengthy, emotional and on-going debate between pure scientific researchers and phenomenologists to a simple dichotomy. The "choice is between two sides... and one cannot have both" (Ackroyd & Hughes,1992). However, if qualitative and quantitative research methods are viewed as opposite ends of a continuum, then there is between them a place for combined qualitative and quantitative investigations - "a binary methodology" (Leedy,1993,139).

In educational research situations a combination of methodologies frequently becomes necessary because the data available generally takes both verbal and numerical form. To focus on only the words or only the numbers would be to ignore a substantial amount of the available data.

A researcher intent upon constructing or testing theories to be generalised would be rigorous in the use of scientific experimental methodology with a strong emphasis on precision, control and replication in order to attain high levels of validity and reliability. A classroom teacher, on the other hand, has specific needs which require urgent action and must translate theory and generalisations into practice (Cohen & Manion, 1989, 228-9).

The action research model has been used in practical educational research since the 1920s. As Hodgkinson put it: "Action research is a direct and logical outcome of the progressive position. After showing children how to work together to solve their problems, the next step was for teachers to adopt the methods they had been teaching their children, and learn to solve their own problems co-operatively" (1957, in Cohen & Manion, 1989, 219). Action research can be defined as a "small scale intervention in the functioning of the real world and a close examination of the effects of such intervention" (Cohen & Manion, 1989, 217).

Characteristics of action research are that it is field focused or situational. It is concerned with solving a particular problem in a specific context (Leedy, 1993, 141). Action research is also participatory. That is, the researcher is actually a participant in implementing the research. This is contrary to the traditional research process in which the researcher is distanced from and careful not to interact with subjects for fear of introducing bias. The dual role of teacher-researcher precludes such a dispassionate stance. However, many theorists and researchers now advocate the participant-observer role as necessary for genuine phenomenological research, as Hackman put it " If you aspire to breakthrough research, stay insistently close to your phenomena", or to quote Bob Grice, "Always handle your own rat" (in Frost & Stablein, 1992).

As well, action research is self-evaluative: "modifications are continuously evaluated within the ongoing situation, the ultimate objective being to improve practice in some way or another" (Cohen & Manion, 1989, 217). These characteristics make action research particularly appropriate to the teaching situation and in fact most teachers are involved in informal action research regularly as they implement new school or state policies in their classrooms or adapt teaching materials to suit individual needs. The main limitations of action research are its lack of sufficient controls and replicability since it is context specific and qualitative by nature.

The 'teacher as researcher' role is an important source of educational development and change (Elliot, in Dunkin, 1987, 162-164). However, the ethical constraints attached to teaching are such that the deprivation of a random group of learners from what may be reasonably considered a beneficial educational material or experience by their teacher is difficult, if not impossible to justify. This being the case the use of a control group for the sake of rigorous scientific method was discarded.

Furthermore a traditional ABA research design where data is taken while a treatment is not present,the treatment is applied and is then removed again was obviously not possible since in an educational setting such as this learning is not conveniently reversible (Martin, 1985,89).

7.2 SMALL N RESEARCH DESIGN

In order to gain higher validity and reliability in the findings relating to the target group of less able learners the single case or small n multiple baseline experimental design was employed. Multiple baseline designs have been described as the "methodological kingpins in the functional analysis of behaviour" (Jones et al, 1977). They entail the use of a baseline period in which data on typical subject behaviour is gathered, followed by an experimental manipulation intended to change the level of the selected behaviour conducted as a time-series analysis.

Single-subject time-series research has a long history stretching back to early experiments in psychology and physiology performed on individual organisms at the beginning of the nineteenth century (Barlow & Herson,1984). It has since been applied to problems in behavioural psychology, psychiatry, counselling, developmental psychology, school psychology, educational psychology and special education (Kratochwill, 1978). Single-subject research refers to the method by which the data is analysed individually rather than to the literal number of subjects. That is, each subject's responses are individually examined rather than averaged with other members of an experimental or control group (McCormick, 1992).

Other important features of single-subject research include: independent variables are directly manipulated; interventions are planned and monitored; pre-experimental baseline data is collected; variables are frequently and repeatedly measured; one independent variable at a time is manipulated; measurement conditions are standardised; strong controls for internal validity are used and external validity is established through replication (McCormick, 1992).

Single subject designs are powerful, simple and very applicable (Bullis & Anderson, 1986). This methodology facilitates teacher research by offering the necessary tools for conducting valid research in the classroom (Halle, 1984). The method is particularly applicable to integrated special education situations where it allows the teacher to readily gain useful individual data (Repp & Brusca, 1983).

A survey carried out by Stile (1988) of single-subject research in early childhood special education from 1977 to 1986 revealed that multiple baseline designs were used most frequently but that there was an overall lack of awareness of the efficacy of single-subject research designs. More emphasis in pre-service teacher training on this research model would seem to be required since the ideal of individualised education is accepted by the field. An interrupted time-series design demonstrates experimental control by manipulating historical events affecting individuals without requiring aggregation of subjects and is an excellent research design for special education (Center et al, 1986).

The single-subject research design used in trialing these manipulatives is summarised in the table below:

TABLE 7.1

GROUP	PHASE 1	PHASE 2	PHASE 3
Learning Difficulties (n=4)	Baseline A	FIT KIT B	CUTE KIT C
Regular Class Students (n=14)	Baseline A	CUTE KIT C	FIT KIT B

The independent variable in this trial was the introduction of the kits of manipulatives. It should be noted that the order of introduction was reversed for the two groups of students. This was in an effort to control for multiple intervention interference but also for practical purposes so that the kits could be used by more students simultaneously during group activity sessions.

The dependent variables were accuracy and fluency scores as measured by the parallel Fractions and Time probes. The following table summarises the measurement techniques employed to determine the effectiveness of the manipulatives during this trial.

TABLE 7.2

GROUP	MEASUREMENT TECHNIQUE
Learning Difficulties (n=4)	Daily % accuracy probes in Fractions & Time Weekly combined fluency probe / 2 min
Regular Class Students (n=14)	Pretest & Posttest % accuracy probes in Fractions & Time Fluency combined Fractions & Time / 2 minutes

The duration of the trial was 8 weeks (40 school days) with time-lagged introduction of phases or interventions to provide replication and control. In fact the duration of the trial differed as determined by the staggered introduction of the kits for the learning difficulties group. The regular class students averaged three forty minute sessions per fortnight working with the manipulatives.

The criterion of mastery was set as 100% accuracy and a fluency score of 17 correct per 2 minutes. This was determined on the basis of the nature of the measurement probes which were designed to assess specific objectives as discussed in Chapter 4 and on a reasonable, competent fluency rate.

7.3 CONSIDERATIONS OF RELIABILITY AND VALIDITY

The two most important considerations with any form of measurement are validity and reliability. Validity is concerned with the effectiveness of the measuring instrument - that is, whether it measures what it is supposed to measure and how adequately it does so (Leedy, 1993, 40). A close match between the content of instruction and the items used in the measurement instrument is strong evidence of content validity (Tawney & Gast,1984,88). The measurement probes used here were directly related to the objectives and content of instruction used in the manipulative kits.

Reliability is concerned with accuracy of measurement - that is, how accurately the instrument measures what it is supposed to measure (Leedy, 1993, 42). The achievement of the same results on successive trials or the successful replication of experiments is evidence of reliability (Tawney & Gast,1984,88). The use of a multiple-baseline design with staggered interventions was used to provide replication in this trial.

Threats to validity in small n research include: (References:Kratochwill, 1978,12-17; Tawney & Gast,1984, 91-3):

HISTORY. Events that are extraneous to the independent variable but that occur concurrently may produce change in the dependent variable. However, the multiple baseline across subjects model controls for history.

MATURATION. Physical or psychological changes may occur in subjects over a period of time which affect their performance on the dependent variable. Avoidance of an extended time-series experiment should have reduced this factor.

CHANGES IN EXPERIMENTAL UNIT COMPOSITION. Some subjects may fail to complete the experiment. Their characteristics may need to be taken into account in order to avoid false conclusions being drawn. In classroom research this is a frequent concern with the high levels of illness and frequent changes of school experienced by many children with poor learning histories.

TESTING. Testing effects can occur when the measurement process itself stimulates change in the subjects either positively or negatively. The establishment of a steady baseline should control for testing effects.

INSTRUMENTATION. The use of unreliable or inconsistent measuring devices may confound results, as can change in the method of measurement. Parallel forms of the testing instrument were provided in this case to overcome this possible source of error. The fact that stable baseline conditions were obtained using these probes provides strong evidence that they were in fact parallel forms.

MULTIPLE INTERVENTION INTERFERENCE. Where two or more interventions are conducted on the same data series false attribution of an effect to the intervention may occur where a combination of the intervention and previous interventions is actually being reflected. In the current study a dual intervention effect was expected due to the interconnections deliberately built into the FIT KIT and the CUTE KIT of Fractions and Time. The decision to introduce the FIT KIT first to the remedial group was based on the fact that the least complicated concepts being taught related to Fractions and were being used as a lead in to the teaching of Time. Hence the parallel probes commenced with Fraction items. Accuracy data was recorded and analysed in two sections - Fractions and Time - so that multiple intervention interference effects could be noted. Fluency data was collected on the combined probes in order to simplify data collection and to make provision for the reversal of intervention order for the rest of the class.

INSTABILITY. Repeated measurements of a single subject typically show some degree of variability. If this variability is large it could mistakenly be attributed to the intervention. In real settings large effects are sought if changes in practice are to be instigated, which guards against spurious instability effects gaining unfair significance. In the research discussed here the use of a multiple baseline design was adopted to control for such errors.

REACTIVE INTERVENTIONS. A researcher must guard against intervening into a data series when the baseline data series is at an extreme value thereby increasing the shift in the data series in the hypothesised direction. This sort of reactive intervention can also threaten the validity of pre-test post test designs such as that used in the research on the rest of the class reported here.

SELECTION. Differential subject selection may interact with other sources of invalidity unless random subject selection occurs. Classroom-based research makes random subject selection impossible and defeats the real motivation behind such studies. Rather, adequate subject data and awareness and acknowledgment of possible interfering factors should be of concern to the researcher in interpreting results (Kratochwill, 1978, 12 - 19).

Once the researcher has secured the internal validity of a small n design the external validity must be considered. However, "control of internal invalidating influences is absolutely necessary, since, if results are internally invalid, generalisation is meaningless" (Kratochwill, 1978, 20). The use of a multiple baseline design across subjects as used here provides a form of time-lagged control since the same experiment is replicated over different subjects with all other factors held constant. This provides for a greater degree of generalisation than the other n=1 designs. Sidman (in Bass,1987) argues that replication of an experiment with two subjects actually establishes greater generality for the data amongst individuals of a population than replication with two groups of subjects whose data has been combined.

7.4 VISUAL ANALYSIS OF DATA

The "seductiveness of statistics" (Leedy,1993, 43) which are actually tools of research rather than facts or truths, and the 20th century dependence on grouped data, a reversion to Aristotelian universals (Bass,1987), has led to an ongoing debate amongst researchers as to the reliability of small n research findings. Visual inspection of graphed data is the primary method of analysis (Tawney & Gast, 1984). Such data should convey to the reader the experimental design; the sequence of baselines and interventions; the time spent in each condition; the independent and dependent variables and the relationship between them (Tawney & Gast, 1984).

The use of various statistical processes has been suggested and implemented including ANOVA and linear regression models of small n research data (Center et al,1986). However, the debate continues surrounding the appropriateness and usefulness of statistical analysis of individual data. The problem is that statistical analysis can overlook large changes in behaviour which visual analysis would not. On the other hand, small but important behavioural changes may be overlooked or discounted by visual analysis alone (DeProspero & Cohen, 1979). As Sidman (in Bass, 1987) observes differences that are significant within any specific statistical method for handling variability may be of little consequence as far as any experimental manipulations are concerned. On the other hand statistically inconsequential differences may be of great importance behaviourally.

Reliance on visual analysis and inference with small n data results in the detection of large, clinically significant effects and remains the most widely used method of analysis. In part this is due to the fact that adequate application of statistical methods is frequently impossible due to the small number of data points available for analysis. For instance, five data points is usual in baseline phases whereas 50 to 60 points may be required for useful statistical analysis (Center et al, 1986).

Accordingly, for the remedial students, visual analysis with a multiple baseline design and weekly fluency data were used in the research reported here. In addition, pre-test and post-test fluency and accuracy data were recorded for the remainder of the regular class students.

CHAPTER 8 - RESULTS AND CONCLUSIONS

8.1 COLLECTION OF DATA

The FIT KIT and the CUTE KIT were trialled on one intact mixed ability class of 18 Year 3 children in the Upper Hunter region of N.S.W. using a pre-test post-test action research model but incorporating a small n multiple baseline methodology on the learning difficulties target group. Both qualitative and quantitative data was sought relating to the perceived effectiveness of these kits of manipulatives.

Qualitative data was collected through observation, and a simple survey. Quantitative data was collected by using repeated parallel probes as measures of Time and Fraction accuracy of the targetted pupils, as well as a measure of number of responses divided by the time taken, giving a measure of fluency for the pupils in the target group of four children with learning difficulties (R1, R2, R3, R4).

Baseline data was taken and averaged for the remainder of the regular class (S1 through to S14) to establish a steady state of competence before the intervention (Martin, 1985, 88). Parallel post-test probes were used to determine the effectiveness of the interventions, along with pre-test and post-test fluency measures of the number of correct responses over the time taken.

The primary focus of the researcher was on the effectiveness of the two kits of manipulatives in assisting the learning of the four individuals experiencing learning difficulties in mathematics. The secondary focus was on the effectiveness and appropriateness of the materials for the other members of the mixed ability class. The same teaching materials and parallel forms of the assessment probes were used in both cases.

The four individuals experiencing learning difficulties, two girls and two boys, (R1, R2, R3, R4) tested in the 2 to 3 stanine range using standardised ACER tests in Mathematics, Reading Comprehension and Reading Vocabulary. The rest of the class fell in the 4 to 7 stanine range. School records showed a long history of learning difficulties and slow progress throughout their short school careers. In three out of four cases their siblings had experienced similar difficulties in school learning. The remaining child was the eldest and only school-age child in her family.

The testing of the kits of manipulatives was conducted over an eight week period (40 school days). During the first week baseline data was collected from the whole class to establish the current levels of competence and fluency existing amongst the children in relation to the Fraction and Time objectives selected for study.

The limited variability of the target group's scores indicates both that the probes were parallel in difficulty and content and that no obvious test learning effect was evident during this baseline period. The baseline data of the regular class students (S1 - S14) was averaged in order to get a general indication of their pre-intervention accuracy and fluency in Time and Fractions. The data relating to fluency or response time is displayed in the graphs. The wide variation in competence and fluency in such a relatively small class is of interest since this is the reality which faces most primary teachers daily.

After five days the first of the target group children (R1) commenced using the FIT KIT. Daily probes were administered to this child along with his three peers. Five days later the next subject (R2) commenced using the FIT KIT with subject (R1) acting as a buddy in partner activities. Administration of the probes continued daily. After another four days had elapsed the third (R3) and fourth (R4) subjects commenced using the FIT KIT. It was originally planned that the system of staged interventions would continue for the group of four children with learning difficulties. However, as can be seen in the baseline data a negative testing effect had become evident with the third and fourth subjects since they were experiencing frustration at being required to undertake repeatedly a task at which they could not succeed which was different from their usual school experience. Rather than risk real antagonism or resistance to the repeated probes it was decided to introduce the initial intervention (B - the FIT KIT) to the last two subjects simultaneously as can be seen in the graphical data on page 149. Once each of these four subjects had completed Set A and Set B of the FIT KIT they proceeded onto the CUTE KIT: on Day 15 for subject R1; Day 20 for subject R2; Day 25 for subject R3 and Day 30 for subject R4.

The order in which the four subjects entered into the treatment was determined by how quickly they evidenced a stable baseline. It was not previously determined or influenced by the researcher in order to avoid a reactive intervention effect.

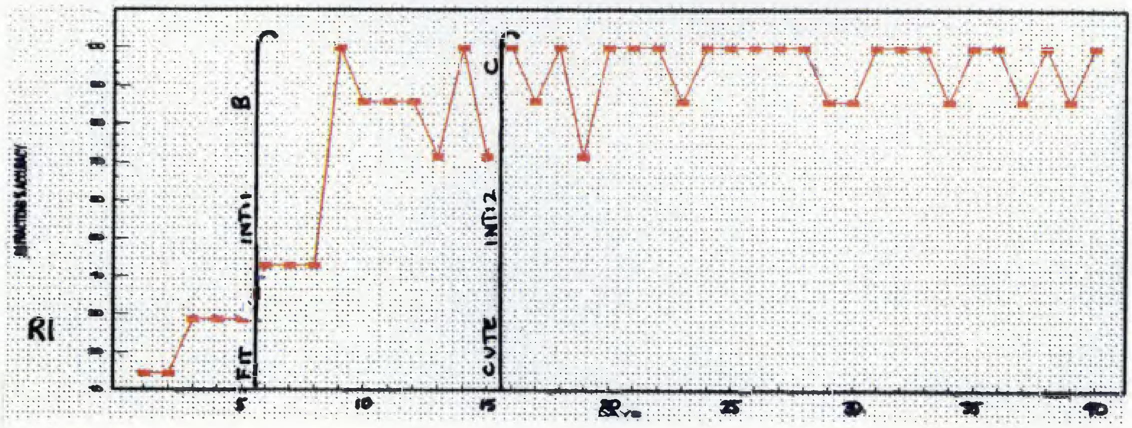
The use of both accuracy and fluency data to evaluate the effectiveness of these materials was primarily because these are important outcomes in mathematics teaching for teachers and students and are in line with the N.S.W. Mathematics K-6 Syllabus (1989) objectives and outcomes. A further reason for obtaining more than one measure of effectiveness is the desirability of using "several frames of reference or perspectives in the analysis of the same set of data" (Leedy, 1993, 143) to provide triangulation which indicates more strongly than a single measure that an effect does in fact exist.

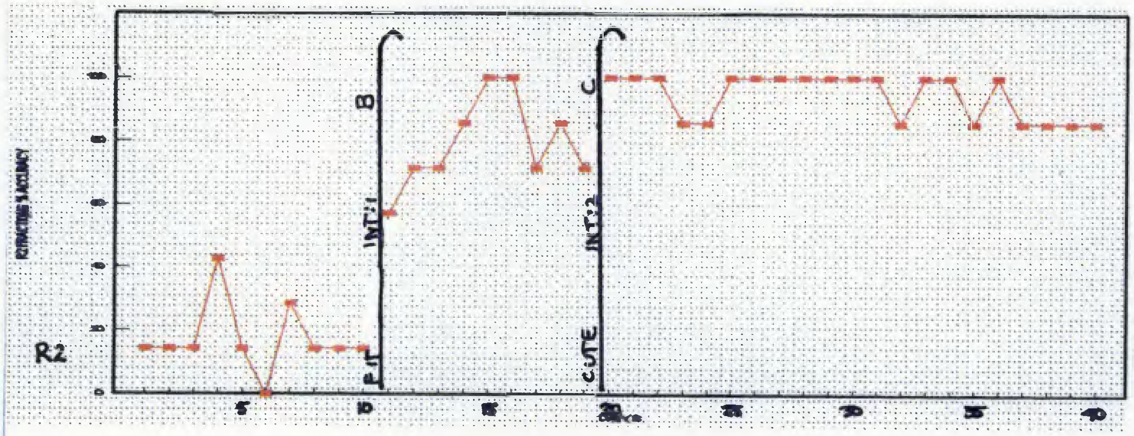
8.2 RESULTS FOR THE LEARNING DIFFICULTIES GROUP

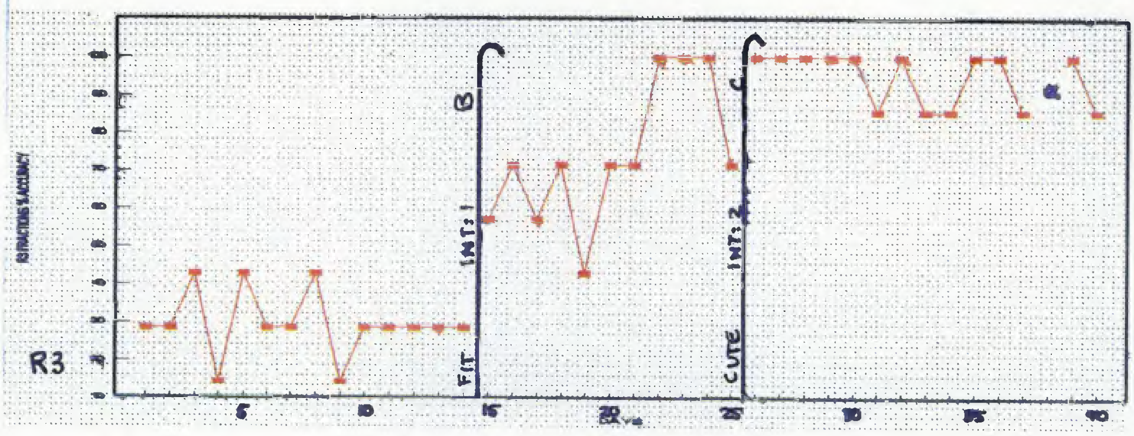
The data collected for the target group of children with learning difficulties can be found on the following pages.

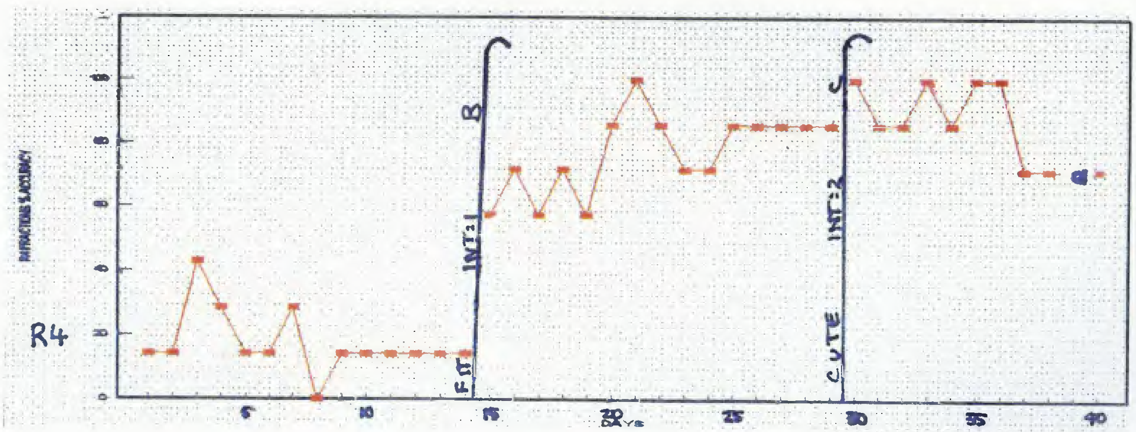
As can be seen from the graphs of Fractions % Accuracy, in each case the children in the learning difficulties group (R1, R2, R3, R4) improved in accuracy in Fractions skills after the FIT KIT was introduced. In all four cases these students attained the 100% criterion regularly during the trial. Students R1 and R2 also showed an improvement in Time accuracy whilst using the FIT KIT, which was hypothesised, due to the deliberate connection between the two areas built into the design of the kit. Students R3 and R4 did not show this effect. This was possibly due to their very poor initial Time skills as revealed during the baseline period, that is, they had very little existing structure and so were less able to make 'connections'.

GRAPHS ON THIS PAGE (LINE GRAPHS) - FRACTIONS % ACC

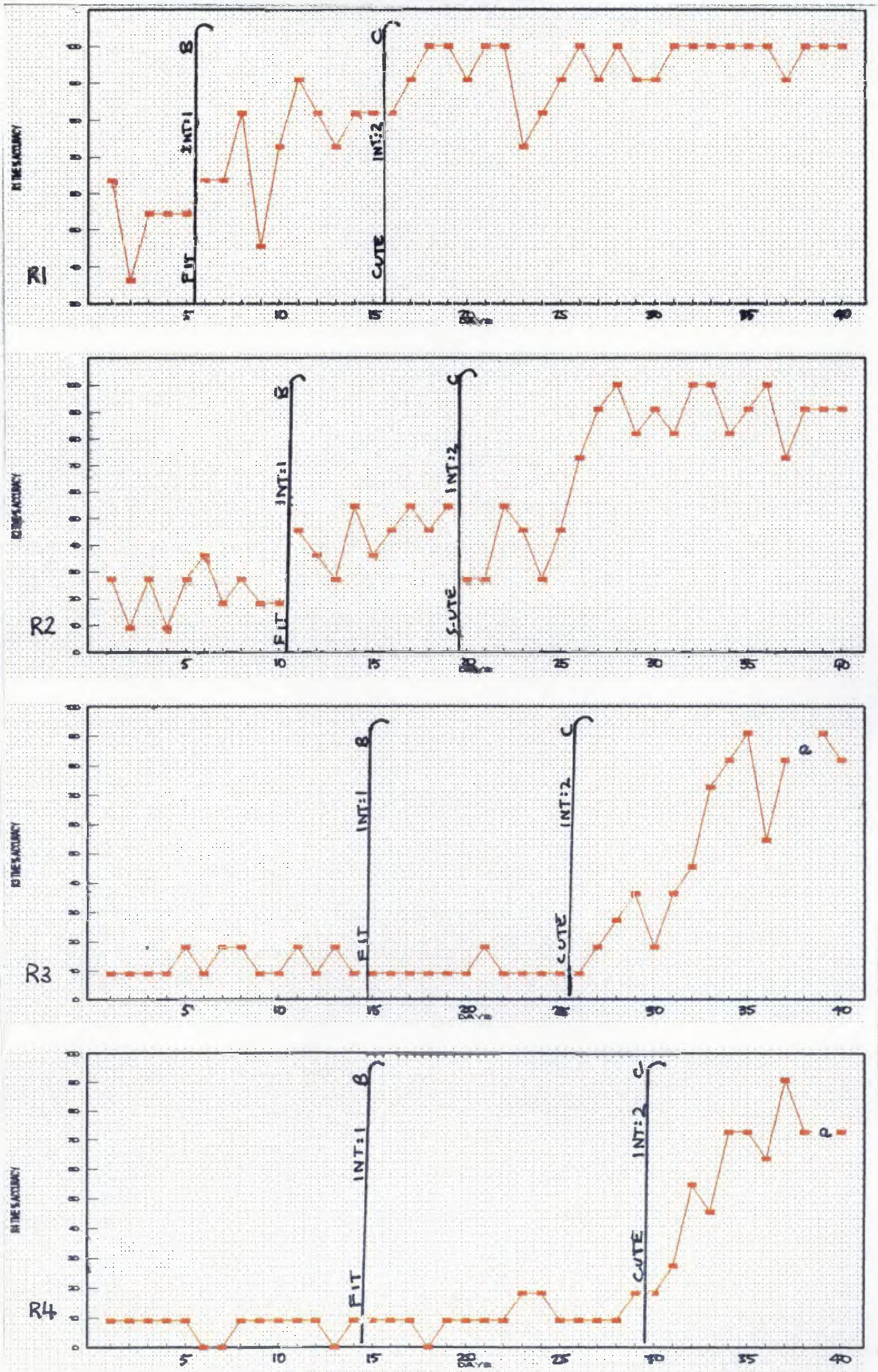




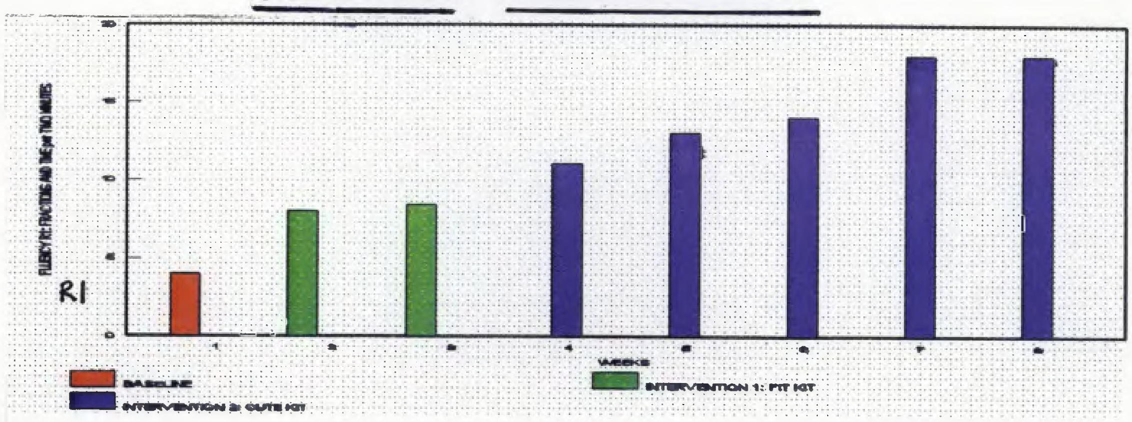


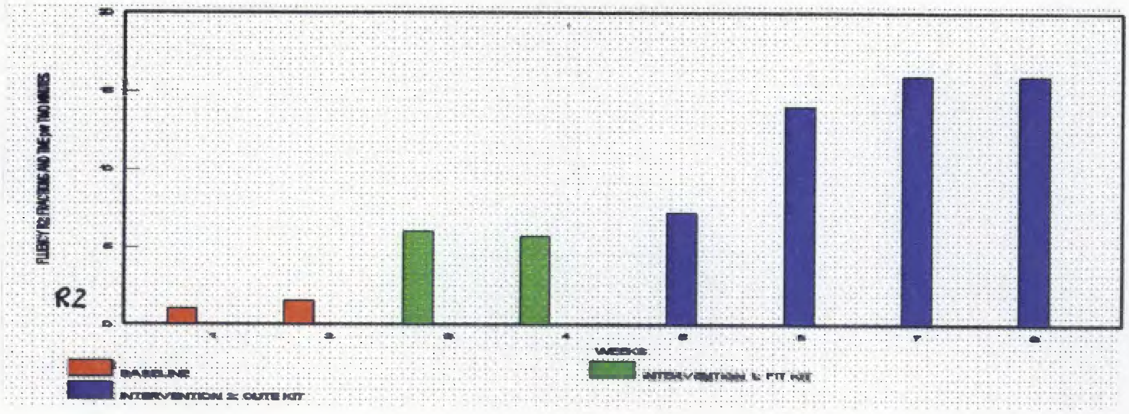


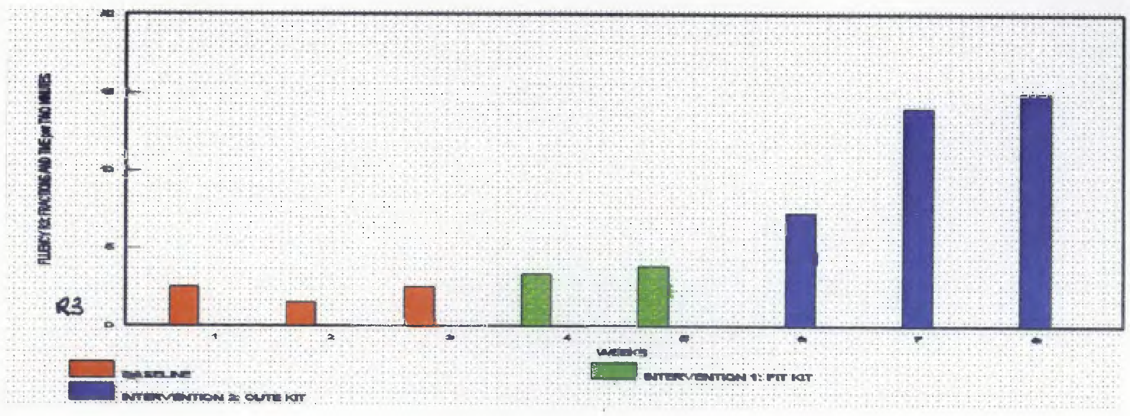
GRAPH PAGE - TIME % ACCURACY

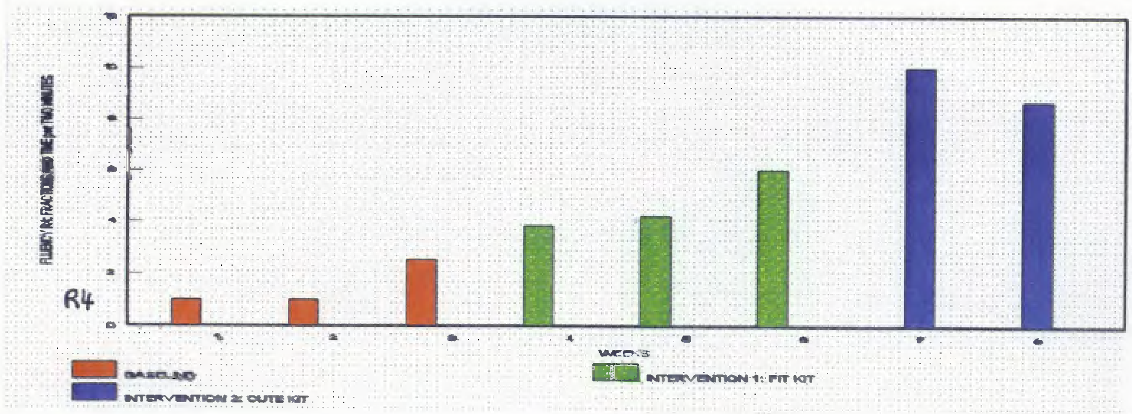


GRAPH PAGE - REMEDIAL FLUENCY









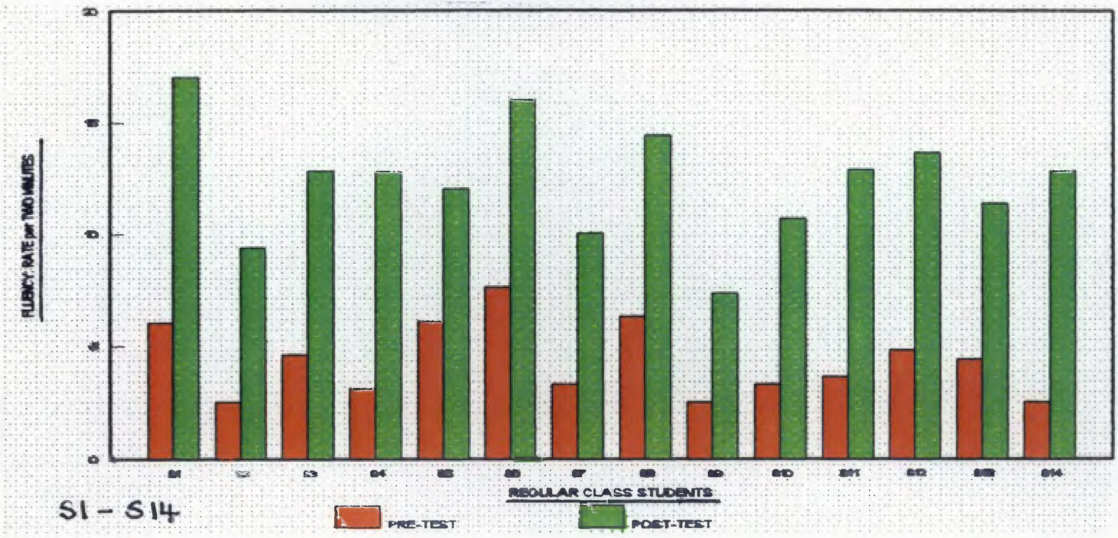
The Time % Accuracy data similarly showed a definite increase in Time skills in all the learning difficulties subjects after the staggered introduction of the CUTE KIT. The mastery criterion was reached in all cases, albeit weakly in the case of subject R4. It would seem reasonable to hypothesise that this subject's scores would continue to improve over time as did those of his peers.

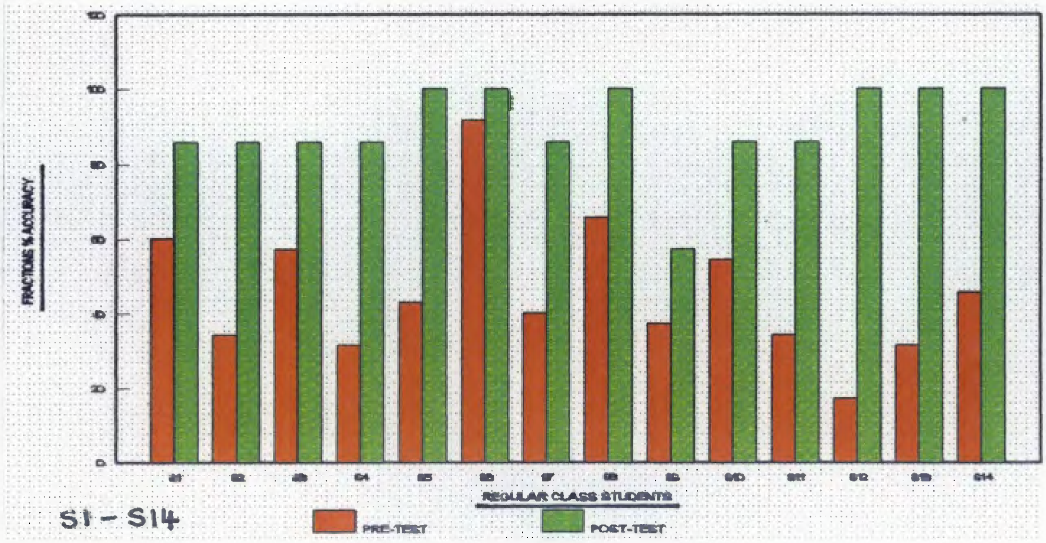
With regard to Fluency, the data displayed in the graphs clearly show an increase in fluency scores over the trial period and indicate the impact of the introduction of the kits of manipulatives. The mastery criterion of 100% of test items correct in 2 minutes was reached by three out of four of the learning difficulties subjects. Only the fourth subject failed to reach criterion within the time of the trial. This was probably due to the reduced amount of usage of the learning materials caused by the time-lagged introduction of the manipulatives.

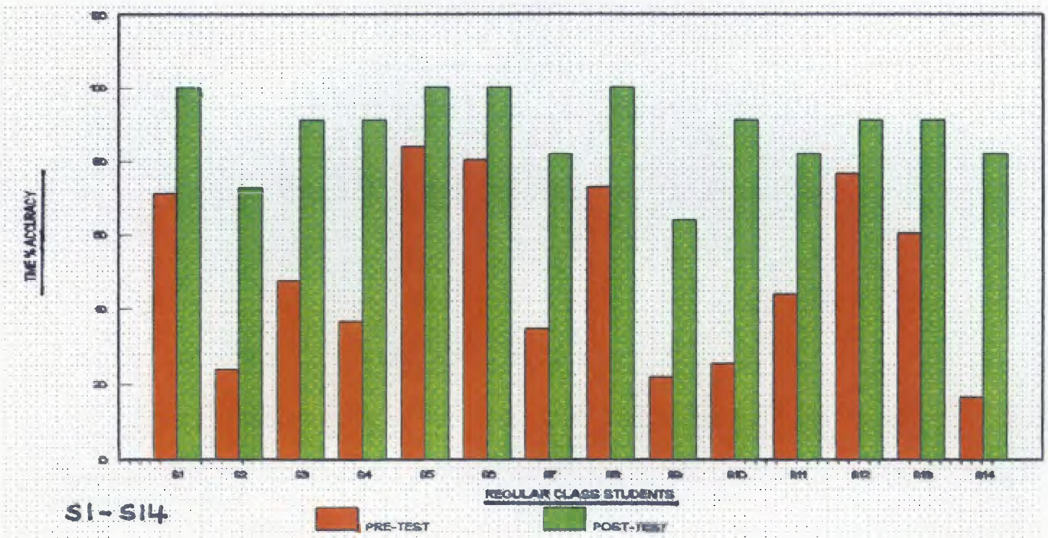
8.3 RESULTS FOR THE REGULAR CLASS STUDENTS

The pre-test post-test data on the regular class students can be found in graphs on page 153. It is clear from the data that all of the students improved in accuracy in Fractions and Time and in fluency in both these areas after using the CUTE KIT and the FIT KIT.

GRAPH:"REG CLASS STUDENTS"







The variability in the levels of entry skills of the students is of interest. However, in terms of accuracy the scores after the trialing of the manipulatives were less variable and generally high, with the exception of student S9. One of the real advantages of this research methodology and style of data presentation in terms of teaching is that individual data is retained and can be used in planning and remediation.

The fluency data for the regular class students was more variable although all subjects showed a definite improvement. The FIT KIT and CUTE KIT were both designed to cater to this sort of normal class variability by providing Set C activity cards with extension activities involving problem solving and applications for the more able students to use whilst their peers developed fluency and accuracy using the Set A and B cards at a slower rate.

8.4 CLASSROOM ORGANISATION

The target group used daily 40 minute mathematics sessions to work with the manipulatives in the FIT KIT and the CUTE KIT. The remainder of the class proceeded with other classwork which in no way related to Fractions or Time.

Once all of the target group had commenced using the FIT KIT, by Day 15, the remainder of the class was assigned to use the CUTE KIT materials in pairs during three mathematics lessons per fortnight whilst their peers were engaged in other tasks. The most able pupils worked rapidly through the basic early cards in the A and B Sets of the kit and proceeded quickly on to the more challenging Set C activities.

8.5 QUALITATIVE DATA

Qualitative data on the effectiveness of these manipulatives was sought through teacher observation of subjects interacting with the materials and through a simple survey of the children's evaluation of the kits (included as Appendix X).

Comments recorded during the experimental period included:
"This is really cool!"
"Can I come in at lunchtime and do the FIT KIT?"
"Am I going to get a go at the FIT KIT today?"
"Oh. I see how it works!"

Results of the survey were as follows:
In rating the FIT KIT 44% of the class classified it as O.K.; 38% as good; and 16% as very good. In rating the

CUTE KIT 38% of the class rated it as O.K.; 11% as good; and 50% as very good.

In terms of the children's perception of the purpose and usefulness of these manipulatives all of the respondents made comments relating to the actual objectives of the kits. For instance, answers to Questions 3 and 4 included:

"The FIT KIT helped me to learn about clocks and fractions"(R1) and

"Learn about time. Now I can read a clock" (S10). Also,

"The CUTE KIT helped me to understand clocks a lot" (R3) and

"to read the time more easier" (S2).

Question 5 asked how often the students would like to use the kits. Answers ranged from 50% for 'sometimes' to 6% for 'every week', with 44% opting for 'every day'.

The children were interested in using the kits initially and their interest continued. All of the children rapidly became proficient at finding their answer booklet and progress card. They gained great satisfaction from using the coloured stickers to mark off their progress, and were trustworthy and independent in marking their answers. The kits remained in good order throughout the experimental period which indicated that they were not only durable but that the children valued them and were concerned enough to look after them.

Some of the more interesting and thoughtful comments made by the students on the survey forms included:
"It is fun and I don't get confused" (S9).
"It is not so hard" (R2).
"It was fun and a good thing for children" (12).
"It is a good fraction teacher" (S10).

8.6 DISCUSSION AND CONCLUSIONS

An enormous amount of academic and research time has been spent over the last several decades on the identification and definition of children with learning problems. Evidence for the retention and support of such children in the regular classroom has been presented and is mounting. Currently, in Australia, policy in both government and non-government schools is to primarily service these children within their normal class peer group. The need for the teaching of both understandings and skills in mathematics has been identified as a major area of educational concern. The teaching of the mathematics of Time and Fractions has been discussed, as well as the need to teach connections between these two areas and their real-life applications.

Factors relating specifically to the effective teaching of children with learning problems have been discussed. Similarities and shared characteristics of problem and normal learners have also been identified.

The issue of how to effectively use concrete materials or manipulatives to enhance the mathematical understandings and skills in Fractions and Time for middle primary students with learning difficulties in the regular classroom has been examined from many different perspectives.

Relevant educational and mathematical theories were examined along with common belief systems of educators in an effort to identify major trends in teaching programs and materials. The impact of theory upon teaching and learning was also examined.

Research relating to the teaching of Fractions and Time to primary students with learning difficulties was examined and found to be scarce or not directly related to improving effectiveness of teaching or materials.
Research into the design of concrete materials and the connections to be made between the areas of mathematics was more useful to the issue under investigation. Specifically related research to the problem under

consideration was sought and presented. However, little related research is currently being undertaken and published. The field is in fact still wide open and little understood.

The current N.S.W. Mathematics K-6 (1989) Syllabus was examined in detail with regard to its theoretical underpinnings, aims, and objectives in relation to the teaching of Fractions and Time. International documents and recommendations were also examined in this regard.

In an effort to discover what content and methods were being used in the teaching of Fractions and Time in regular classes in the Upper Hunter region and whether students with learning difficulties were remaining in regular classes or being withdrawn for specialist tuition a survey of mathematics textbook usage was undertaken.

This survey revealed a strong emphasis on textbook usage to teach mathematics in the schools surveyed, as well as a wide range and variability in the amount of content covered and work units provided in the preferred texts.
Further examination of the texts in terms of how adequately they complied with the aims, objectives and recommendation of the N.S.W. Syllabus (1989) revealed that heavy dependence on textbooks would provide insufficient revision, practice and extension for most

regular classes, and that effective use of manipulatives would be highly recommended.

The justification for the frequent use of concrete materials in the teaching of primary mathematics was outlined, along with factors to increase effectiveness and warnings regarding ill-considered usage. The issue of the usefulness of open-ended concrete materials was also raised.

A review of generally available mathematical manipulatives relating to the teaching of Fractions and Time was carried out in an effort to ascertain likely or possible concrete materials which could be used to supplement textbooks and implement the curriculum recommendations. It was discovered that many manipulatives currently available were appropriate for use as enjoyable drill activities to consolidate learning rather than promoting concept development in the initial learning stages. The areas of Fractions and Time were not connected in these materials and on the whole they were not clearly related to real life mathematics learning.

An attempt was made to design and trial two kits of manipulatives relating to the teaching of Fractions and Time in a connected fashion to a middle primary class in the Upper Hunter region of NSW. Four students in this regular class who were experiencing learning difficulties were involved in a multiple-baseline single-subject research design. Fluency and accuracy scores on parallel Fraction and Time probes were used to determine the effectiveness of the manipulatives in assisting these students to develop concepts and skills in these areas. At the same time, the remainder of the regular class trialled the CUTE KIT and the FIT KIT in a less intensive pre-test post-test fluency and accuracy experiment. Qualitative data was also collected in the form of anecdotal records of teacher observations during the trial period and a simple written student survey carried out following the trial.

Visual analysis of the numerical data indicated that the FIT KIT and the CUTE KIT were effective for both the learning difficulties group and the regular class students in increasing their accuracy and fluency in relation to the Fractions and Time objectives selected. The qualitative data indicated that the students were able to perceive the purposes of the kits, enjoyed using them, believed that they had assisted their learning of Fractions and Time concepts and skills and would be prepared to continue to use the kits on a regular basis.

8.7 FUTURE DIRECTIONS

Further trials across a variety of classrooms and age groups would be necessary to establish the general usefulness of the manipulatives developed in this study. Nevertheless, such a specific and small scale study provides evidence that classroom teachers can effectively devise and implement effective programs tailored to the specific needs of their students, including those students with learning difficulties integrated into regular classes.

The use of the single-subject research design was found to be practical for classroom use and particularly suited to this intensive, small group situation. However, this design is currently under-utilised and computer statistics and graphing packages need to be developed to assist teachers in keeping visual records and planning changes in programs. Whilst existing computer packages can be adapted to suit such data, a need exists for dedicated single subject research graphical displays.

Minor technical difficulties with the kits were experienced during the trial. The small digital dots for the wooden digital clock models in the CUTE KIT were too small and easy to mislay. These were replaced by adhesive circular dots which were much more practical. Also, the kits were boxed in plastic storage containers. Larger containers with compartments or individual containers for the components of the kits would be necessary to keep the equipment in good order and accessible to large groups of students.

Further activity-based, manipulative kits closely aligned to research and curriculum recommendations could be developed for general classroom use in areas such as Space and Measurement which require extensive practical experience. The incorporation of remediation and extension within the activity cards and the student's responsibility for recording their own progress were important elements in the design of the manipulatives trialled here and should be retained in any future kits.

Lastly, awareness of connections between mathematical areas and between mathematics and real-life situations needs to continue to develop in teachers and students if we are to maximise students' development of mathematical competencies and applications of mathematical skills and understandings beyond the classroom.