

**THE DEVELOPMENT OF PATTERN-RELATED ABILITIES THROUGH
PLAY ACTIVITIES IN YOUNG CHILDREN**

by

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The candidate confirms that the work submitted is her own and that appropriate credit has been given where reference has been made to the work of others.

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ABSTRACT

This thesis investigates nursery children's knowledge, understanding and skills in pattern-making as an aspect of early mathematical development. It presents two discrete but closely related studies, a cross-sectional and a longitudinal study. The methodology includes use of structured assessment activities using familiar play materials. Assessment focuses firstly on different aspects of pattern-making; secondly, on pattern perception; and thirdly, on wider aspects of developing cognition. The methodology includes collection of case study data in the naturalistic setting of the nursery class.

The cross-sectional study, focused on knowledge, understanding and skills in pattern-making at 3½ and 4½ years, finds an increasing minority of children successful in repeated pattern-making and 2D spatial pattern-making but not linear symmetrical pattern-making. Few children evidence pattern perception at either age but an increasing minority evidences an emergent understanding of the word 'pattern.'

The longitudinal study tracks children's development towards and within pattern-making from 3½ to 4½ years. It details development in two key aspects of pattern-making, colour and spatial organisation, through case study data. An examination of commonalities in development leads to hypothesised developmental pathways in both aspects of pattern-making. A single pathway leads towards complex colour organisation. Distinct pathways lead to basic and complex spatial organisation and to the basic elements of pattern. Pathways to 2D spatial pattern-making are more varied than pathways to repeated pattern-making. Quantitative analysis confirms key features of the pathways although some findings remain tentative.

Differences in the detail of individual pathways are highlighted, as are wide differences in children's rates of development and in their interests and motivation. There are no findings of significant gender-related differences. Children's competencies in the colour organisation strand of pattern-making are significantly associated with abilities across key areas of developing cognition. Spatial organisation competencies are at first associated with a narrow range of primarily spatial abilities but this extends to include number and rhythmic abilities at 4½ years. The study confirms and extends some earlier findings, and also presents new findings. Findings lead to questioning of guidance on curriculum goals and pedagogy for the age-group. They highlight a need to acknowledge the creativity of many young children in this area of mathematics.

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INTRODUCTION

Over the last two centuries, there have been many changes to the content of the mathematics curriculum for young children in the English education system. Similarly, there have been many changes in pedagogical approaches to the implementation of this curriculum (Gordon and Lawton 1978). Over recent decades, the focus on pattern as a strand of the early years mathematics curriculum has been subject to particular change. Most recently, as the pace of change has quickened, different aspects and approaches to work with pattern have been highlighted in the informal and more recently formalised curricula for young children from three to five years of age.

At times, curriculum change in mathematics for the youngest children in the education system has been closely allied to change within the wider context of the infant or primary school curriculum. At other times, for example with the introduction of the National Curriculum, the model of the secondary school curriculum has impacted on curriculum change for the youngest children (Anning 1997).

Additionally, there have been changes to the presented rationale for the mathematics curriculum over the years. From the 1950's onwards, statements from educators and academics about the mathematics curriculum have often placed pattern at the very heart of this curriculum. Fletcher's views place him in the mainstream of recent thinking about the mathematics curriculum:

Mathematics is concerned with structural relations between concepts of number and the application of these concepts to environmental situations. These structural relations (which can be considered as algebra) form patterns, and it is the discovery, classifying and superimposing of these patterns that form the essence of mathematical activity and thinking. (Fletcher 1970, p.2)

In recent decades, curricula and related guidance have been developed in particular from this influential perspective (Frobisher et al. 1999).

Over the last decade of the 20th century, prescribed change to the mathematics curriculum and to the place of pattern within this curriculum has impacted on the mathematical learning of increasing numbers of young children across a widening range of early years settings. Change in the form of a statutory mathematics curriculum first impacted on five year olds in school reception classes with the introduction of Mathematics in the National Curriculum (DES 1989). More recently with the Desirable Outcomes for Children's Learning (DfEE 1998), change has impacted on the mathematics curriculum for young children in nursery schools and classes, as well as many young children in playgroups and a variety of day-care settings, including private nurseries and early years centres. With the implementation of the Curriculum Guidance for the Foundation Stage (DfEE 2000) from September 2000, there are newly prescribed goals for the mathematical learning of all children in the now wide range of state

funded educare settings. These prescribed goals are for children of three to children at the end of their reception year.

AIMS AND OVERVIEW OF THE STUDY

AIMS

As a nursery teacher, working within a primary school, my particular interests in young children's creativity and their mathematical learning were the starting points for this study. These interests came together through my involvement with and observation of young children as pattern-makers in a nursery classroom, using a wide range of creative and mathematical materials.

As a primary teacher from the early 1970's onwards, I had also experienced the impact of the frequent changes to content and pedagogy that characterised the primary curriculum in the second half of the 20th Century. With my particular interest in pattern within the early years mathematics curriculum, I set out on this study in response to the particular changes in emphases on the place of pattern within this curriculum.

We are working in a period of rapid curriculum change, with complex political and economic forces impacting on the development of curricula (DfEE 1997). I therefore believe that it is important that any reformulation of mathematical goals and guidance on pedagogy be informed by detailed knowledge and understanding of firstly, young children's competencies and secondly, effective approaches to teaching and learning. Where goals are prescriptive, as with the 'Curriculum Guidance for the Foundation Stage' (DFEE 2000), it is particularly important that both the goals for children's learning and the guidance about development and implementation of the curriculum are underpinned by relevant research.

Set in the context outlined above, the broad aim of this study was firstly, to evaluate the research base underpinning recent changes to the focus on pattern within the early years mathematics curriculum, identifying any gaps or areas of relative weakness in this base. Secondly, and contingent on the results of this evaluation, the aim was to undertake empirical research focused on one or more of the areas of identified weakness, in order to inform any future reformulation of curriculum goals and guidance.

OVERVIEW

Chapter 1

Moving on from the initial presentation of aims, the first chapter details the background to the study, with a summary of changes to the early years mathematics curriculum and the place of pattern within that curriculum over the last two centuries. The summary focuses in particular on changes to the content of the curriculum and changes to pedagogy over the last half century.

To conclude this summary, the recently introduced foundation stage mathematics curriculum and its particular approach to pattern is presented. Finally, the chapter ends with a presentation of the key issues raised by the historical background.

Chapter 2

Following this historical overview, Chapter 2 presents a review of the research literature relating to the pattern related competencies of young children. The first part of the literature review focuses on young children's knowledge, understanding and skills in repeating pattern work. It also includes a focus on developmental issues and theories relating to young children's competencies in the area of repeated pattern-making. The second part of the literature review focuses on young children's knowledge, understanding and skills in identifying and making 2D shapes and patterns. Again, developmental issues are considered as well as relevant theoretical work. The literature review concludes with an evaluation of the research base underpinning recent changes to the focus on pattern within the early years mathematics curriculum.

With this evaluation and the identification of areas of weakness in the research base completed, Chapter 2 then begins the process of framing the research questions to be taken forward into the main study. The literature review, however, supports the delineation of a broad area of focus for the main study only. It does not, in Chapter 2, support framing of the precise research questions to be investigated in the main study. The process of framing these questions is delayed until Chapter 3, until the initial and exploratory stage of the research has been undertaken.

Chapters 3 and 4

Chapter 3 presents two pilot studies with distinct aims and methodologies. The aims of the first pilot study are firstly, to explore a broad research focus on children's pattern-making activity in a nursery setting; secondly, to refine the broad research focus into a set of specific research questions; and thirdly, to support the planning of an appropriate research strategy as well as the methods and techniques to be employed in the main study. Chapter 3 presents an outline of the methodology and the key findings of the first pilot study. It concludes with a presentation of the five main study research questions arising from the study. The second part of Chapter 3 focuses on the methodological issues raised by the first pilot study. Consideration of these issues prepares the way for planning the methodology to be used in the main study.

In the third part of Chapter 3, the second pilot study is presented. Working from the refined set of research questions relating to young children's pattern related competencies, the aims of this study are to trial, evaluate and amend firstly, new pattern assessment activities and secondly, a set of wider assessment activities for use in the main study. In Chapter 3 these assessment activities are presented and evaluated. This prepares the way for the presentation in Chapter 4 of the finalised research design for the main study.

Chapter 5, 6 and 7

With the empirical research completed, the findings relating to each of the main study research questions are presented in chapters 5, 6 and 7. Research questions are considered individually and, where questions are closely related, as complementary. Both qualitative and the quantitative data arising from the main study are presented.

The main focus of Chapter 5 is on the presentation of findings relating to the knowledge, understanding and skills in pattern-making of young children at 3½ and 4½ years. The findings relate firstly, to young children copying, continuing and devising linear repeated patterns; secondly, to children devising spatial patterns; and thirdly to children co-ordinating colour and spatial organisation in pattern-making. Finally, data relating to children's declarative knowledge and their understanding of pattern as a mathematical concept is presented.

The main focus of Chapter 6 is on the presentation of findings relating to the development of young children's knowledge, understanding and skills in pattern-making between 3½ and 4½ years. Findings relating to two strands of pattern-making, colour organisation and spatial organisation, and to children's co-ordination of these strands are presented. Additionally, the presentation of findings focuses on individual differences in children's knowledge, understanding and skills in pattern-making. Individual differences in pathways towards pattern-making, as well as differences in children's rates of development of knowledge, understanding and skills in pattern-making are considered.

The main focus of Chapter 7 is on the presentation of findings relating to the ways that individual differences in children's knowledge, understanding and skills in pattern-making at 3½ and 4½ years are associated with differences across other dimensions of development.

Chapter 8

In the final chapter, Chapter 8, the research findings relating to young children's pattern related mathematical competencies are summarised and these findings are compared with the findings of previous research. Differences in relation to earlier findings are noted and discussed. The important new findings arising from the study are highlighted. Following this, the study's effectiveness is evaluated, firstly in answering the main study research questions and secondly, in achieving its broader aims.

Chapter 8 then moves on to consider the implications of the study in terms of the focus on pattern within the foundation stage mathematics curriculum. The implications for foundation stage practitioners in terms of their planning for learning and teaching are reviewed. Finally, some of the ways in which the research could be taken forward through future studies are considered.

CHAPTER 1

HISTORICAL BACKGROUND

PATTERN AND THE EARLY YEARS MATHEMATICS CURRICULUM

This section presents an outline of changes to both the pedagogy and the content of the mathematics curriculum for 3 to 5 year olds, from the early 19th century until the present day. The mathematics curriculum for this age group is examined within the wider context of both the early years curriculum for 3 to 7 year olds and the primary curriculum. Particular consideration is given to the changing status, exemplification and rationale for any focus on ‘pattern’ and ‘pattern-making’ within the primary mathematics curriculum and in particular the mathematics curriculum for the early years.

The extended historical background provides a context to support understanding of the particular changes to the early years mathematics curriculum that have taken place over the last half century, leading to prescribed early learning goals within a foundation stage curriculum at the beginning of the new century. Towards the end of the chapter, this new foundation stage mathematics curriculum and its particular approach to pattern is presented. To conclude the chapter, the issues raised by the review of the historical background are summarised

THE 19th CENTURY: CONTINUITIES AND CHANGE IN THE EARLY YEARS CURRICULUM

Utilitarianism

Throughout the 19th century, there were many children in Britain who attended school from as young as 3. Compulsory education for children over 5 did not begin until 1876. Throughout the century, however, schools were used to provide a cheap form of child-minding for many young, working-class children. The conditions were bleak and learning mainly sedentary for most young children in the early dame schools, the monitorial schools and the infant schools during this period (Anning 1997).

The young children of middle class families, however, were unlikely to be found in these schools. While some attended private schools, many middle-class families employed private tutors.

This segregation of educational settings in relation to social class was in keeping with Utilitarianism, which Gordon and Lawton (1978, p.56) describe as “the dominant social theory” of the period. One consequence of Utilitarianism as a social theory was the predominant view that the school curriculum should be matched to the different roles that would be ascribed to children from different social classes in their future lives. It was considered that a segregated system best supported this match of education to social role.

The Mainstream Mathematics Curriculum

Within this segregated education system the curriculum for the majority of young children was narrow and the only aspect of mathematics likely to feature in this curriculum was arithmetic, taught through drill. Gordon and Lawton (1978) outline the way that arithmetic was viewed as a low status subject throughout the 19th century, useful only for the children of the working classes. Consequently, arithmetic was taught in isolation from other more abstract aspects of mathematics and was not considered as a suitable subject for children in the public schools, where geometry and algebra were more likely to be taught. When ‘payment by results’ was introduced into the elementary schools in 1862, the system of rote learning and the narrow mathematics curriculum were powerfully re-enforced.

Experiments in Early Years Education

For a minority of 3, 4 and 5 year olds, from working class and middle class families, school life in this period was likely to offer more varied and probably more enjoyable experiences than those outlined above. From the beginning of the 19th century, early childhood education had been developing very gradually as a distinct phase of education. Spodek and Brown (1993) describe some of the earliest experiments in the field. These include Owen’s first infant school, established in Scotland in 1816 for the children of mill workers, and Froebel’s first kindergarten, created in Germany in 1837, for the young children of middle class families. In these new schools the early years curriculum was widened beyond the basic diet of reading, writing and arithmetic and young children were given opportunities to play. Froebel in particular was developing a new view of childhood, one in which play was valued as a serious and creative activity and considered to be “an essential part of the educational process” (Spodek 1973, p.39). In both Owen’s and Froebel’s own classes, new teaching methods, allowing for some more independent learning, were introduced and consideration was given to children’s understanding.

Froebel’s primary aim in developing a new kind of early years curriculum was to promote children’s spiritual learning. Consequently, he considered play primarily in relation to spiritual goals. Froebel did not recognise the mathematical potential of children’s play with the innovative shapes apparatus used in his kindergarten, for example the 3D shapes known as the ‘gifts’. To promote children’s spiritual learning, play with such apparatus was tightly prescribed by adults and it probably provided few opportunities for exploration of the mathematical properties of apparatus.

In the kindergartens that were developed in Europe and the United States, modelled on Froebel’s first kindergarten, young children continued to play with a wide variety of purposefully designed apparatus. Despite Froebel’s own focus on spiritual aims, it can be noted that some of the apparatus used in the 19th century Froebelian kindergartens continued in use into the 20th century and had potential for developing young children’s mathematical knowledge, understanding and skills beyond the traditional confines of arithmetic. The unrecognised

potential for mathematical development in aspects of pattern-making through the use of geometric wooden blocks, as well as bead and button stringing, is particularly high.

Child Development

Spodek and Brown (1993) suggest that, although the scientific study of development in childhood was yet to begin, such experiments in early childhood education provide evidence of a new and intuitive understanding of the nature and needs of young children. They also provide evidence of an understanding of the ways in which a distinctively early years curriculum might be matched to the characteristics of young children as learners. However, during the 19th century, these new approaches to learning were to remain outside the mainstream of educational provision for young children.

THE EARLY 20th CENTURY: CURRICULUM DEVELOPMENT

Control of the Curriculum

Towards the last years of the 19th century and moving into the first years of the 20th century, there was some widening of the elementary curriculum. In addition, the potential for further curriculum change grew as central control of the school curriculum was reduced. Gordon and Lawton (1978) outline the history of the legislation and reports of government committees that formed the background to these changes. In 1926, the Elementary Regulations were abolished, ending government prescription of the elementary curriculum. However, although by the late 1920's teachers had gained a high level of autonomy in relation to the elementary school curriculum, they did not take immediate advantage of this to initiate change.

An Infant Curriculum: Froebelian Methods

From the end of the 19th century, there had been some official encouragement of Froebelian methods and the wider use of practical materials in the elementary school curriculum. Gordon and Lawton (1978, p.149) refer to a list of officially approved activities in a circular issued to inspectors at this time, including practical apparatus to support mathematical learning. The list includes "mosaic with coloured paper and gum", as well as "cutting out patterns and shapes with scissors" and "number pictures with cubes and beads".

Some Infant Headmistresses had enthusiastically adopted new approaches to pedagogy from around the turn of the century. However, the new approaches were firmly rejected by most elementary school teachers until much later. Gordon and Lawton suggest that this was, in part, because successful Froebelian practice was considered to be dependent on a teacher working with small groups of children.

The Hadow Reports

Anning (1997, p.4) describes how further official encouragement for new approaches to pedagogy came with the Hadow Reports of 1931 and 1933. The first report recommended that infant education be developed as a distinct phase of education for children from 3 to 7. The second report recommended that the curriculum be developed in terms of “activity and experience rather than of knowledge to be acquired and facts to be stored.” However, despite some encouragement for more active approaches to learning, the report continued to emphasise the importance of drill in the teaching of reading, writing and arithmetic (Gordon and Lawton 1978).

Through the early years of the 20th century, there continued to be five year olds, some four year olds and sometimes three year olds present in infant classrooms, mostly in large classes and sometimes with older children. Theoretically teachers controlled the curriculum but there was no political will to reduce class size. Consequently for most young children, the mathematics curriculum continued as a narrow diet of arithmetic to be learnt by rote.

Montessori

The 19th century tradition of experimentation with a distinctively early years curriculum did continue into the first years of the 20th century, although the effects were not widespread. The work of Maria Montessori provided a new and significant influence in this period. Montessori’s innovative approach to the education of working class children, exemplified by the Casa dei Bambini set up in the slums of Rome, inspired an international movement that led to the establishment of Montessori schools across the world, including England. Montessori was a doctor and a psychologist. Her work is an early example of the way in which growing knowledge of child development came to shape a distinctive curriculum for young children in the 20th century.

Montessori’s curriculum, as described by Spodek (1993), contrasted sharply with the traditional curriculum of the elementary schools in England, with their emphasis on drills and the rote learning of narrow and utilitarian subject matter. Montessori’s innovative curriculum was wide, with a high value placed on developing understanding through practical experience. Teaching was focused on activities and materials that would enable children to develop knowledge through sensory experience. This was considered to be an essential stage in young children’s learning, providing a foundation for later symbolic experiences.

This approach shaped learning in mathematics. Special graded apparatus, often self-correcting, was devised to support children’s developing understanding of number. Similarly, although there was no explicit aim to develop a mathematics curriculum widened beyond the traditional confines of arithmetic, several items of structured apparatus were used to focus children’s perception on aspects of space and shape. Montessori’s young children were allowed high levels of independence in organising their time and in selecting materials. The curriculum

emphasis, however, remained firmly on play with structured rather than open-ended materials. The child's response was prescribed by the nature of the materials and an exploratory approach to the patterning of play materials, for example, was not encouraged.

The Macmillans

In the early years of the 20th century, pioneering work in the education of young working class children was also taking place in England, where Rachel and Margaret Macmillan opened the first nursery schools. 'Open air' schools were opened in the slums of Bradford and London, where the poor physical conditions of children's lives enforced a heavy toll on both their physical and intellectual development. While these early nursery schools placed considerable emphasis on nurturing children physically, there was also an emphasis on developing a curriculum to promote intellectual development.

Spodek (1993) describes how perceptual- motor learning was emphasised in the Macmillan's nursery curriculum, with some use of sensory-training materials similar to those developed by Montessori. However, the Macmillans did not adopt the Montessori curriculum as a whole, criticising its neglect of children's imaginative abilities and the limited role ascribed to the teacher.

Despite retaining some elements of the traditional elementary curriculum, with the teaching of reading, writing and arithmetic to five year olds, the Macmillans pioneered a wider early years curriculum. Their innovative curriculum incorporated interesting first hand experiences, for example gardening and water play in the nursery garden, and it provided varied opportunities for physical play. It also placed a new emphasis on the creative and imaginative exploration of materials.

As with the Montessori and Froebelian curricula, there was no articulated aim to develop a mathematics curriculum widened beyond the traditional confines of arithmetic. However the play materials used in the 'open air nurseries' included materials that could be used to focus children's perception on aspects of space and shape, for example wooden blocks and handicrafts materials. Like the influential early years curriculum of Froebel, this new curriculum carried the potential for supporting young children's wider mathematical development, including development in some aspects of early pattern-making.

The Study of Child Development

In the first half of the 20th century, child development grew as a distinct and important field of study within the new discipline of psychology. Spodek (1993) describes how the child study movement, with research focused on a broad spectrum of children, brought new influences to bear on the development of a distinctive curriculum for the early years. He outlines the area of research led by Stanley Hall and his student Arnold Gesell, which set out to establish norms of development in children of different ages. The interest of many teachers in the new

developmental theory supported new approaches to curriculum planning, with educational experiences matched to children's levels of development. During the first two decades of the 20th century, the Progressive Reform Kindergarten movement in the United States undertook reform of the Froebelian kindergarten model, influenced by Stanley Hall and Gessell's work on developmental norms and by the writings of John Dewey.

Examining the influence of the developing discipline of psychology on the early years curriculum, Spodek highlights two further influential areas, behaviourist learning theories and psychoanalytic theory.

Susan Isaacs

The influence of theoretical developments on the early years curriculum is exemplified by the pioneering work of Susan Isaacs at the Malting House School in England from the 1920's onwards. Both Anning (1997) and Athey (1991) highlight Isaac's work and key achievements. Working up until the late 1940's, Isaacs was influenced by the ongoing research of Piaget and by contemporary Freudian theories of child development, with their new focus on young children's emotional and social development.

Isaacs worked at a private school with the privileged children of middle class families. As a result her thinking was more intently focused on children's intellectual development and less on their physical well-being than the thinking of the Macmillan sisters, working in the slums of Bradford and London. Isaac's curriculum, however, paralleled that of the Macmillan sisters in terms of the important role given to both play materials and first hand experiences.

Isaac's work was innovative in that influenced by developmental theory she redefined the role of the early years teacher. Isaacs worked in her school as a teacher-researcher, with research focused on children's intellectual growth. She used observation as a key teaching and research tool, believing that, to effectively support children's learning, the teacher must co-ordinate "observation, theory, teaching and evaluation" (Athey 1991, p.17). Isaac's definition of the adult role as an interventionist guide, supporting children's individual explorations of the physical environment and facilitating their access to curriculum materials, was not widely influential at the time. However, Isaac's model of the early years teacher seemed to anticipate the major changes to the teacher's role that were to be seen across Europe in the second half of the century, arising out of reform of the primary mathematics curriculum

THE 1960s AND 1970s - 'NEW MATHS'

For most young children in the first half of the 20th century in Britain, the traditional elementary mathematics curriculum, with its narrow focus on arithmetic, remained relatively unchanged. Drill, with learning by rote, remained the predominant teaching method. From the late 1950s, however, the pace of change accelerated and, by the early 1970s, the primary

mathematics curriculum had been radically restructured for many children. Arithmetic, now likely to be labelled 'number', was still an important topic within the primary mathematics curriculum. However, it had undergone significant change and now took its place alongside other major topics.

The early 1970s had introduced early work on pattern, including spatial patterns and linear repeating patterns, as topics or strands within the infant mathematics curriculum. Additionally, new approaches to pedagogy had resulted in an increased emphasis on children's exploration of mathematical apparatus and play materials.

Forces for Change

The forces for change that had been building up over the previous decades were varied and they were interrelated in complex ways. Bob Moon (1986) details these forces for change and the complex history of curriculum reform across Europe from 1960 to 1980. In Britain in 1960, schools still had considerable autonomy over the school curriculum. In 1972, looking back over a decade of change, the authors of *Mathematics in Primary Schools* (Schools Council 1972, p.1) stated that, "One of the interesting features of our educational system is that reforms have usually come from within the schools themselves and have not, primarily, been made in response to external pressures." However, although there was pressure for change coming from within the schools, Moon's (1986) analysis indicates that there were also many external forces.

The Universities

The universities were the first powerful force for change. The great expansion of mathematics that had taken place in the universities during the 19th and early 20th centuries had resulted in a growing gulf between school and university mathematics. The universities wanted change in the school mathematics curriculum to ensure that new students were better prepared for the university mathematics courses. Thompson (1997) describes how, in the 1930's, the Bourbaki group took on an influential role in attempting to codify the new mathematical knowledge. The work of this group made use of the precise mathematical language that became associated with set theory. In the 1960s and 1970s set theory was developed as a key feature of the new primary mathematics curriculum.

Developments in Psychology

Secondly, developments in psychology led to pressure for curriculum change. Child development was a rapidly growing area of research in this period and the work of a number of psychologists influenced the development of the mathematics curriculum. Taylor (1976), reviewing the impact of psychological theory on the infant mathematics curriculum, cites Dienes, Bruner, Lovell, Piaget and Bryant as key influences.

Of these psychologists, however, it was Piaget who was most influential in supporting definitions of both the content and the pedagogy of the new curriculum. Moon (1986) refers to Piaget's influence on the Association of Teachers of Mathematics. He also reports on the impact that Piaget's work had on the early work of the Nuffield Mathematics Teaching Project. This project was widely influential and it helped to shape the 'new maths' curriculum in England and Wales. Early in the development of the Nuffield Project, two project members visited Geneva, to increase knowledge and understanding of Piaget's work, and this visit laid the foundation for later collaborative work with Piaget on the development of assessment materials

The influence of Piaget's research on the pedagogy of the new mathematics curriculum was acknowledged in 'Maths With Everything' (The Nuffield Foundation 1971, p.2). This book, providing background information about the project for teachers and parents, summarised the influence, "Piaget's message was simple... young children learn by getting involved, by acting, by experiencing mathematics rather than just learning it from a book."

Economic Forces

The third force for change was economic. In the 1960s, a period of rapid technological change, industrialists in Britain believed that a better educated work-force was critical to economic success. During this period, industrialists were a force supporting modernisation of the mathematics curriculum.

Moon (1986) outlines how the success of the Russians with the launch of the first Sputnik, in 1957, was a further spur to reform. This event, challenging the current view of Russia as backward in both maths and science education, led directly to the release of federal funds for curriculum development in the U.S.A. Moon argues against the view that the launch of Sputnik influenced curriculum development across Europe. However, the development of the mathematics curriculum in the U.S.A. that followed this event was closely paralleled by curriculum development in Britain and Europe.

The Nuffield Mathematics Teaching Project

The forces for change outlined above led to the Nuffield Foundation launch of a reform project, focused on the primary mathematics curriculum (Moon 1986). This project, led by Geoffrey Matthews, was a major influence on changes that were made to the primary school mathematics curriculum in the 1960s and 1970s.

The Nuffield curriculum was exemplified through a series of project guides. Primary mathematics was divided into three major topics, 'Computation and Structure', 'Shape and Size' and 'Graphs Leading to Algebra.' Mathematics Begins (Nuffield Mathematics, Project 1967b) was the first in the 'Computation and Structure' series. It outlined the new pre-number and early number curriculum for the pre-school and early infant years. Beginnings (Nuffield Mathematics

Project 1967a) were the first in the series on 'Shape and Size'. This guide outlined the new maths curriculum relating to shape and measurement for this age group.

Nuffield Mathematics and Pattern

In the innovative pre-number curriculum, as outlined in *Mathematics Begins* (Nuffield Mathematics Project 1967b), there is a new focus on mathematical relations, sorting, one to one correspondence, conservation, ordering and inclusion. In the section on ordering, it is suggested that children copy and reverse copy a sequence of shapes. However, there is no reference to repeating sequences. Advice relating to the use of number patterns is introduced towards the end of the guide, with suggested activities appropriate for 6 and 7 year olds.

In *Beginnings* (Nuffield Mathematics Project 1967a), there is a far greater emphasis on mathematical patterns and pattern-making, with several areas of play provision discussed in terms of their potential for spatial pattern-making. In a section on "picture and pattern making," it is advised that young children use a wide range of media in exploratory and self-directed work. Printing is highlighted as a media particularly supportive of early pattern-making. 'Bricks and constructional play' are also valued for "the symmetry of the patterns and models that are made" (The Nuffield Foundation 1967a, p.22).

The guide acknowledges the spatial pattern-making skills of some young children; it recognises the mathematical potential of exploratory play with materials; and it encourages teachers to support children's thinking about spatial patterns through talk. However the guide does not propose any detailed sequence of development for children's work, "Their first prints are usually random in character, with no order about them, but occasionally a child will at once produce a highly symmetrical pattern" (1967a, p.12).

In summary, the Nuffield Mathematics Project strongly emphasises the mathematical potential of work on spatial patterning for infants; it emphasises the value of work with number patterns for children at the older end of the age range; and it introduces some work on copying but not repeating sequences of objects. Although some of the activities for younger children would have been familiar as play, handicraft or art activities in some earlier infant classrooms, the Nuffield Mathematics Project makes the mathematical potential of these activities explicit. Finally, it is important to note that, while the Nuffield Mathematics Project provides detailed information on developmental sequences in the area of number, it does not provide this advice on developmental sequences in relation to pattern.

'Fletcher Maths'

The Nuffield Mathematics Teaching Project was a major influence on the development of the mathematics curriculum in primary schools into the 1970s and beyond. Another important influence was *Mathematics for Schools* (Fletcher 1970), another primary maths scheme. Fletcher, the author of this scheme, was a key figure in the Nuffield Mathematics Project team

before he embarked on his own commercial project (Moon 1986). Fletcher's scheme, with its pupil workbooks as well as teacher's handbook, was a commercial success throughout the 1970s.

In addition to differing approaches to the use of pupil materials, an important difference between the Nuffield and Fletcher schemes is the different emphasis and approach taken to the theme of pattern in the mathematics curriculum. Within the infant stage of the Nuffield scheme, there is a strong focus on exploratory, spatial pattern-making but a limited focus on other aspects of pattern. No explicit reference is made to 'pattern' as an integrating theme in *Maths With Everything* (The Nuffield Foundation 1971), the guide providing an overview of the Nuffield infant curriculum.

In contrast, in the introductory section to 'Mathematics For Schools' (Fletcher 1970), Fletcher makes explicit reference to the view that 'pattern' is at the heart of mathematics and this view is reflected throughout the scheme. For example, the scheme provides an early focus on work with repeating and sequential number patterns using varied apparatus and this focus is sustained throughout Level 1 of the scheme. Children are introduced to pattern-making in varied contexts through the experience of continuing repeating patterns. They then have opportunities to devise many different kinds of repeating patterns.

However, while *Mathematics for Schools* (Fletcher 1970) places a greater and an earlier emphasis on number patterns than the Nuffield scheme, Fletcher's emphasis on spatial patterns comes later in the scheme and is more limited in scope. In 'Beginnings' (The Nuffield Foundation 1967a) there is an early emphasis on the provision of opportunities for 2D and 3D pattern-making during environmental play. In contrast, in *Mathematics for Schools* (Fletcher 1970) there is no reference to play of this kind until the section on 'Symmetry', the last section of Level 1, "Whenever the children make patterns with bricks, or on a geoboard, symmetrical qualities are likely to appear" (Fletcher 1970, p.236). The work on spatial patterns that follows is restricted to 2D work, with the focus on prescribed rather than exploratory activities.

Nuffield Maths 5-11

In 1979 the Nuffield mathematics scheme was re-launched, meeting demands for a new structured scheme of materials for teachers and pupils (Moon 1986). Changes were made to the presentation of materials and also to the content of the curriculum, including pattern related content. A focus on number patterns earlier in the scheme brings the revised Nuffield scheme closer in content to the successful *Mathematics for Schools* (Fletcher 1970). However there is still no practical strand on sequential and repeating patterns to parallel the strand running through Level 1 of *Mathematics for Schools* (Fletcher 1970).

Additionally, in the revised Nuffield scheme, there are changes in the approach to 2D and 3D pattern-making, again bringing the scheme into line with *Mathematics for Schools* (Fletcher 1970), but in this case by reducing the focus on pattern. The original Nuffield emphasis

on exploratory, environmental play is reduced with a now almost token suggestion that, “In the early stages, the main task for the teacher is to encourage in children an awareness of the shapes, patterns and space around them” (Moore 1979, p.103). There is a brief reference to children making patterns with drawing, painting and printing materials in the section on ‘Shapes and space’ (Moore 1979). However the focus of this chapter is more narrowly on the properties of 2D and 3D shapes than on work with spatial patterns.

THE LATE 20th CENTURY: THE MATHEMATICS CURRICULUM

The 1980s - A Non-Statutory Mathematics Curriculum

Starting in 1989 and continuing through the following decade, significant changes were made to both the status and the content of the mathematics curriculum offered to young children in England and Wales. These changes impacted on young children in nursery schools, in school nursery and reception classes, as well as on young children in non-school settings.

For several decades prior to 1989, there had been no statutory mathematics curriculum for children in England and Wales. The most recent government reports, for example Mathematics Counts (Cockcroft 1982) had provided an authoritative framework for planning the mathematics curriculum in schools, with a focus on the years of compulsory schooling from 5 to 16. However, an H.M.I. survey of mathematics education carried out between 1982 and 1986 (D.E.S. 1989a, p.7) indicates “considerable unevenness” across the different strands of mathematics, as well as “mainly poor” overall performance in about a quarter of the schools surveyed.

Specific findings, relating to children’s work with pattern, parallel these general findings. The HMI report (D.E.S. 1989a) identifies work with number patterns as a key strand within the mathematics curriculum of most primary schools by the 1980’s. However, children’s performance in this strand is judged to be adequate or good in only three-quarters of the classes surveyed. Children’s performance in work relating to geometry is judged to be adequate in only half the schools surveyed.

The First National Curriculum for Mathematics

Beginning in 1989, the statutory implementation of a National Curriculum for mathematics and nine other subjects began. The new statutory curriculum was in part a political response to public and professional concern about the official findings of unevenness in mathematics teaching and in children’s mathematical performance. A new and prescriptive hierarchy of mathematical learning objectives, with exemplification of objectives through detailed activities, was provided for both primary and secondary schools. The aim of the new curriculum was to counteract the unevenness in teaching and learning documented in official reports and so to raise standards in mathematics, as in other National Curriculum subjects.

In *Mathematics in the National Curriculum* (DES 1989b) learning objectives and detailed activities relating to pattern are included in both the Algebra and the Shape and Measure curriculum strands. Suggested activities parallel many found in the earlier Nuffield and Fletcher schemes.

Pattern in Attainment Target 3: Algebra

The 1989 National Curriculum for mathematics, for example, includes the Algebra Level 1 objective to “devise repeating patterns” through opportunities for “copying, continuing and devising repeating patterns represented by objects/apparatus or single-digit numbers”. This is followed by an Algebra Level 2 objective to “explore number patterns” an objective to be achieved by the average child by about seven years of age (DES 1989b, p.10). This work on repeating and number patterns mirrors work in the earlier Nuffield and Fletcher schemes. For example, the work on repeating patterns with objects and apparatus is a key strand running through Level 1 sections of *Mathematics for Schools* (Fletcher 1970).

Pattern in Attainment Target 4: Shape and Space

Additional pattern-making work is detailed as examples in the Shape and Space attainment target. It is advised that children create and describe pictures and patterns using 2D shapes, to support development towards expected levels of understanding of 2D shape by about 7 years of age. To develop ideas of reflective symmetry, it is advised that those more advanced children, working towards Level 3, “explore patterns from a variety of world cultures” and “explore patterns in art or P.E.” (DES 1989b, p.14). This advice on exploratory work with 2D shapes and reflective symmetry parallels earlier advice in *Beginnings* (The Nuffield Foundation 1967a). However the focus on spatial patterns in the National Curriculum programme of study is not evident before Level 2. This contrasts with the earlier focus on spatial pattern-making in the Nuffield scheme. At Level 1 of the National Curriculum programme of study, early years work with 3D shape seems relatively narrow in its focus on the properties of 3D shapes.

Pedagogy

In terms of a suggested pedagogy for mathematical work with pattern, the National Curriculum programmes of study do retain the earlier Nuffield project emphasis on exploratory work and on the potential for mathematical learning within children’s creative work. In addition, within the programme of study for Attainment Target 1, ‘Using and Applying Mathematics’, there is some limited recognition of the need to provide opportunities for the youngest children in school to learn about pattern through creative play with 2D and 3D materials. A Level 1 exemplar activity is for children to “build symmetrical models” (DES 1989b, p.2).

The 1995 Revised National Curriculum For Mathematics

In the 1995 version of the National Curriculum for mathematics (DFE 1995), new programmes of study for using and applying mathematics emphasise the importance of pattern recognition in early years mathematics. The programme of study states that children should be given opportunities “to recognise simple patterns and relationships and make related predictions about them” (DFE 1995, p.22). This is echoed in the Level 1 descriptor, “recognise and use a simple pattern or relationship” (DFE 1995, p.32).

In the programme of study and level descriptors for number, early years work with repeating patterns using objects is again identified as important. The new Level 1 descriptor is “recognise and make repeating patterns, counting the number of each object in each repeat” (DFE 1995, p.33). The use of the term ‘recognise’ in these contexts is new. However, pattern recognition and related prediction is implied by the focus on continuing patterns in the previous curriculum.

As with the earlier curriculum, the focus on spatial pattern-making appears relatively late. Competencies related to spatial pattern-making are excluded from the Level 1 descriptor for Shape, Space and Measures.

A National Curriculum For Three, Four and Five Year Olds?

The new statutory mathematics curriculum was intended for the oldest children within the 3 to 5 year old age range only. Initially, Key Stage 1 of the National Curriculum was defined as beginning “with a pupil becoming of compulsory school age”, the term following the pupil’s fifth birthday (DES 1989b, p.3). From the Spring term 1991, the National Curriculum for mathematics as outlined above became statutory for the oldest five year olds in school reception classes. However, for many of the youngest children in these classes, children who would not be five until the summer term, there was no statutory curriculum until the start of Year 1. These complicated arrangements resulted in reception class teachers working with changing proportions of children entitled to the statutory curriculum. In this context, it seemed likely that the statutory mathematics curriculum would impact on reception children of non-statutory school age.

There is in fact evidence to suggest that the influence of a statutory National Curriculum soon reached down to children younger than those found in school reception classes. Kathy Sylva et al (1992) reports research highlighting a formalisation of some aspects of the early years curriculum in education nurseries during the early period in which the National Curriculum was being implemented.

The Desirable Outcomes

In this confused context, a new document, Desirable Outcomes for Children’s Learning (SCAA 1996), attempted to clarify the mathematics curriculum for those children in state funded

educare settings who were below statutory school age. It prescribed learning goals for children to attain by compulsory school age.

Examined in the context of the early years curricula of the three preceding decades, the pattern related desirable outcome for mathematics seems both narrow and unclear in its expectations. The brief statement of outcome is, “They recognise and recreate patterns” (SCAA 1996, p.3). If the intended reference is to spatial patterns, as well as repeating patterns, then the document introduces a competency not included in earlier curricula, informal or statutory. In earlier infant curricula, from the Nuffield project onwards, references to spatial patterns emphasise children creating and exploring patterns and not copying patterns.

The use of “recognise... patterns” in the desirable outcome mirrors the earlier use of ‘recognise’ in Level 1 descriptors for using and applying mathematics, as well as for number (DFE 1995). The exact meaning of ‘recognise’ for these younger children, however, is not clear.

The desirable outcome use of “recreate patterns” echoes the use of “copying...repeating patterns” in the first National Curriculum for mathematics (DES 1989b, p.10). However, the reference to ‘continuing’ and ‘devising’ repeating patterns that accompanies the reference to ‘copying’ patterns in the original programme of study is missing from the desirable outcomes document. The implication of this omission is that copying or recreating patterns is a developmental achievement prior to devising patterns. The implied developmental sequence also places pattern recognition as a developmental achievement prior to devising repeating patterns.

THE EARLY 21st CENTURY: A FOUNDATION STAGE CURRICULUM

The beginning of the new century was marked by further revision of the mathematical goals for young children in state funded educare settings, with the introduction of a foundation stage curriculum to precede Key Stage 1. The age range for this curriculum was extended to include all children until the end of their reception year. For reception children only, the mathematical goals of this new curriculum reiterate the National Numeracy Strategy key objectives introduced in the previous year (DFEE 1999). The new Curriculum Guidance for the Foundation Stage (DFEE 2000) includes substantial guidance on an appropriate pedagogy for children in the foundation stage with a clear emphasis on children learning through play, “Mathematical understanding should be developed through stories, songs, games and imaginative play ...” (DFEE 2000 p.68).

The new pattern related early learning goal, “Talk about, recognise and recreate simple patterns” (DFEE 2000), is similar to the earlier desirable outcome, “They recognise and recreate patterns” (SCAA 1996, p.3). Change comes with the explicit inclusion of ‘talk’ and with the qualified reference to ‘simple patterns’.

Curriculum Guidance

The extensive guidance in the new document is relatively limited in its references to pattern. There are no references to pattern in the section focused on children's mathematical learning. There is, however, a reference to pattern in the section on teaching mathematics, with pattern recognised as an integrating theme in mathematics:

The idea of 'pattern' runs through the different aspects of mathematics. Children might notice repeating patterns of colours or shapes on a favourite tee-shirt, for example, or they might help to create a repeating pattern with beads. Children begin to appreciate symmetry and this may feature in some of their drawings. They might also notice patterns when working with numbers of objects, for example, 'You get three and I get four. Three, four!' (DFEE 2000, p.73)

The emphasis, as in the early learning goal, is on children's response to recognised patterns, as well as on children's participation in adult led work with repeated patterns. This guidance reinforces the idea of a developmental sequence, first stated by implication in the pattern-related desirable outcome. The proposed developmental sequence places pattern recognition and pattern copying prior to creative pattern-making, in particular creative repeated pattern-making.

Stepping Stones

The curriculum guidance suggests likely 'stepping stones' for children as they move towards the early learning goals. In the proposed stepping stones to the pattern-related early learning goal and the associated shape, space and measures goals, there are relatively few references to pattern related activity. The earliest stepping stones include, "Show an interest in shape and space by ... making arrangements with objects". Following this, the second set of stepping stones include, "Show interest by ... talking about shapes or arrangements" (DFEE 2000, p.78). The third set of stepping stones and the set prior to the early learning goal include, "Sustain an interest for a length of time on a pre-decided ... arrangement." They also include, "Show awareness of symmetry" (DFEE 2000, p.80). There is some ambiguity here as to whether the suggested arrangements of play materials are linear arrangements, 2D arrangements, 3D arrangements or perhaps all of these.

The lists of examples of what children do provide no further clarification of the goal because no pattern related examples are provided. In contrast, there are five examples of children arranging play materials for the purposes of representation. In the lists of examples of what practitioners need to do to support learning there is just one pattern related example provided. This guidance is for practitioners working with children at the earliest stage, "Encourage children to talk about the shapes they see and use and how they are arranged" (DFEE 2000, p.79).

In conclusion, the status of the pattern strand within the Curriculum Guidance for the Foundation Stage (2000) is relatively low. The guidance sets expectations for children to talk

about, recognise and recreate patterns by the end of the reception year. There is, however, no explicitly stated expectation for children to devise their own repeated or spatial patterns.

Individual Differences

The Curriculum Guidance for the Foundation stage (DFEE 2000, p.17) includes a strong and recurring strand of guidance on “meeting the diverse needs of children.” It states that, “Practitioners must be aware that children bring to their early learning provision different experiences, interests, skills and knowledge that affect their ability to learn.” Differences arising from gender, disability and ethnicity are included as areas for consideration. The explicit focus on gender and ethnicity is new in terms of guidance relating to early years curricula. In the earlier Desirable Outcomes for Children’s Learning (SCAA 1996), explicit consideration of diverse needs relates only to children with special educational needs and high abilities.

The National Numeracy Strategy

The National Numeracy Strategy provides more detailed objectives and guidance for reception teachers working with children towards the end of the foundation stage (DFEE 1999). For practitioners in schools, this document does provide some clarification of the pattern-related early learning goal, clarification absent in the later curriculum guidance. In the National Numeracy Strategy, the key objective “Talk about, recognise and recreate simple patterns” is qualified by, “for example, simple repeating or symmetrical patterns from different cultures/in the environment” (DFEE 1999, Yearly teaching programmes, p.2).

Additionally, under the sub-heading, “Exploring pattern, shape and space,” there is an additional objective for reception children, “Use a variety of shapes to make models, pictures and patterns and describe them” (DFEE 1999, Yearly teaching programmes, p.2). There is an expectation here, lacking in the Curriculum Guidance for the Foundation Stage (DFEE 2000), that children will devise spatial patterns by the end of the foundation stage. Additional Numeracy Strategy guidance advises practitioners to promote spatial and repeated pattern-making through the use of a wide range of creative and play materials. It includes suggestions for varied activities relating to linear, 2D and 3D work.

In terms of the pattern strand in mathematics, the National Numeracy Strategy guidance (DFEE 1999) sets higher expectations and provides more detailed guidance for reception teachers than the Curriculum Guidance for the Foundation Stage (DFEE 2000). In terms of its practical advice on the wide range of media that young children might use for spatial pattern-making, Numeracy Strategy guidance mirrors the advice in ‘Beginnings’ (Nuffield Mathematics Project 1967a). However, in terms of its guidance on time allocation, the Numeracy Strategy guidance gives a relatively low priority to work with pattern in reception classes. This is partly because the pattern strand of the curriculum is not as integrated with number work as in the earlier Mathematics for Schools (Fletcher 1970).

CONCLUSION

The mathematics curriculum for three to five year olds has widened in content over the last half century, with increasing numbers of young children gaining access to this widened curriculum. Although there is currently a renewed emphasis on the central place of numeracy in the mathematics curriculum (DFEE 1999), the early years mathematics curriculum remains broad when compared to the utilitarian curricula experienced by the majority of young children prior to the 1960's.

At the same time, there have been widespread changes in pedagogical approaches to the curriculum since the 1960s, with guidance now encouraging early years teachers to promote mathematical learning through child led play and talk, alongside some more adult directed group work. Despite the spiritual rather than the mathematical aims of Froebel's work in the mid-19th Century, Froebel's pioneering approach to young children learning through play with structured apparatus has been widespread and long lasting in its influence on the early years mathematics curriculum.

The innovative Nuffield project of the late 1960s was similarly influential in its approaches to young children's learning. Following the introduction of the Nuffield infant curriculum in 1967, pattern has been included consistently as a strand of early years mathematics curricula and there is now a prescribed pattern related goal in the foundation stage curriculum. However, since the first introduction of pattern into the early years mathematics curriculum, there have been several significant changes in emphasis, as well as changes in expectations.

At the beginning of the 21st century, with the introduction of a foundation stage, there is a confusing lack of congruence in emphasis and expectations between the two sets of guidance for this stage, The National Numeracy Strategy (DFEE 1999) and the Curriculum Guidance for the Foundation Stage (DFEE 200). Although the pattern related Numeracy Strategy key objective and the foundation stage early learning goal are identical, this shared objective is interpreted in different ways and accorded different kinds of status within the two sets of guidance.

Pattern: Key Differences in Early Years Maths Curricula

In summary, some of the key ways that recent mathematics curricula for 3 to 5 year olds have differed in terms of their approaches to pattern are:

- the relative emphasis given to linear repeated pattern-making and spatial pattern-making
- the relative emphasis given to representational work and pattern-making in children's work with 2D and 3D materials.
- the relative emphasis placed on pattern perception, usually children recognising the patterns devised by others, and children creating their own patterns

- the relative emphasis placed on children copying patterns and children creating their own patterns
- proposed developmental pathways to repeated and spatial pattern-making, either explicit or implicit
- expectations, in terms of competencies in pattern perception and competencies in copying, continuing and devising patterns
- the relative emphasis given to the pattern strand of the mathematics curriculum and other key strands in terms of time allocation
- the emphasis placed on a focus on pattern within the number curriculum
- the emphasis placed on individual differences, for example gender and ethnicity
- guidance on the range of media to be used for pattern-making

A Research Base for Curriculum Change?

The rationale for the many differences and frequent change in the pattern related strands of recent early years mathematics curricula have rarely been presented in the curriculum guidance for teachers. It is therefore not clear how far the changes in emphasis and expectations over recent decades have been underpinned by contemporary research findings. As stated in the introduction to this chapter, any reformulation of mathematical goals and guidance on pedagogy should be informed by detailed knowledge and understanding about firstly, young children's competencies, and secondly, effective approaches to teaching and learning. This is particularly important where goals are prescriptive, as with the 'Curriculum Guidance for the Foundation Stage' (DFEE 2000).

To address this issue, this study moves on to an evaluation of the research base underpinning changes in approaches to pattern within early years mathematics curricula from the 1960's onwards. Chapter 2 presents a review of the research literature, focusing on the identified dimensions of difference in curricula summarised above. Evaluation of the research literature supports identification of possible gaps or areas of relative weakness in the research base underpinning recent pattern related curriculum change.

CHAPTER 2

LITERATURE REVIEW: YOUNG CHILDREN AND PATTERN

INTRODUCTION

For the last half century, mathematicians have consistently acknowledged the centrality of a study of pattern to mathematics education. Orton exemplifies this influential view, shaping curricula over recent decades, with statements from mathematics educators from the 1950's onwards (1999). However, in Chapter 1, a review of recent and changing approaches to pattern in early years curricula demonstrated that, despite a consensus amongst mathematicians about the importance of a study of pattern to mathematics education, there has been no consensus about appropriate ways for this study to shape the curriculum. In Chapter 1, the review of changing approaches to pattern led to identification of significant dimensions of difference amongst recent early years curricula.

In this chapter, the underpinning research base for approaches to pattern in the foundation stage mathematics curriculum is reviewed and evaluated. For a full evaluation of this research base it would be necessary to consider firstly, the research literature relating to young children's pattern related competencies and secondly, literature more directly focused on pedagogical approaches to the curriculum. However, due to the limits placed on the breadth of this study, the review of research literature focuses primarily on a review of studies relating to young children's pattern related competencies. The age range for the literature review is three to five years of age, the age span for children in the foundation stage. However, there is some consideration of relevant studies that include children both younger and older than this.

KEY AREAS FOR REVIEW

The review of the research literature and the subsequent evaluation of the research base supporting approaches to pattern in the foundation stage mathematics curriculum is based on the dimensions of difference in early years curricula identified in Chapter 1. Working from these dimensions of difference, the key areas to consider in the literature review are:

- children's competencies in linear repeated pattern-making and spatial pattern-making
- children's relative skills in copying, continuing and devising patterns
- the relationship between children's representational and pattern-making competencies in work with 2D and 3D materials
- pattern perception and children's abilities to talk about pattern
- developmental pathways to repeated and spatial pattern-making
- individual differences, including gender
- developmental distinctions in the dimensions of materials

Additionally, consideration is given to a review of:

- theories relating to young children's developing knowledge, understanding and skills in pattern-making

Outline of the Chapter

Recent early years curricula, as exemplified in Chapter 1, differ markedly in terms of the relative emphasis given to repeated and spatial patterns. In the first half of this chapter, the literature relating to children's repeated pattern-making competencies is reviewed. Following this, in the second half of the chapter, the literature relating to spatial competencies is reviewed. The first half of the chapter concludes with an evaluation of the underpinning research base for approaches to repeating patterns in the foundation stage curriculum. The second half concludes with an evaluation of the underpinning research base for approaches to spatial patterns. Gaps and areas of relative weakness in this research base are identified for each aspect of pattern. Evaluation supports delineation of a broad area of focus to be taken forward into the first pilot study, where the process of defining precise research questions for the main study is completed.

LINEAR REPEATED PATTERN-MAKING

The review of the research literature begins with a review of empirical studies focused on children's abilities to copy, continue and devise repeating patterns during the foundation stage and early years of primary education. Research evidence relating to developmental pathways is also considered. The main studies reviewed include a group of related studies undertaken in the 1970's; two studies in the Piagetian tradition; a recent study focused on National Curriculum expectations; and reports from an action-research project. Following this, the literature relating to perception of repeating patterns is reviewed. The next studies reviewed are studies of early classifying behaviours that may be precursors of repeated pattern competencies. In the following section, some theoretical accounts of the cognitive processes underlying repeated pattern-making are considered.

This part of the chapter then moves on to a summary of key findings, followed by the identification of gaps and areas of relative weakness in the research base relating to young children's competencies in work with repeating patterns. The identification process contributes to the delineation of a broad area of focus on repeated pattern-making to be carried forward into the first pilot study.

THE 1970'S: REPEATED PATTERN STUDIES

Following the commercial success of *Mathematics for Schools* (Fletcher 1970), work with repeated patterns became a significant strand of the early years mathematics curriculum in

the 1970's. A cluster of related studies from the early 1970's examine young children's responses to pattern-making tasks, with a focus on repeated patterns. The studies vary in terms of the age group studied and the particular focus on repeating patterns.

McKillip (1970), studying pattern recognition abilities in 3, 4 and 5 year olds, presents evidence of improvement with age in young children's abilities to copy and continue model patterns. Cromie's study (1971) similarly reports developments in children's work with repeating patterns between 4 and 7 years of age. It also provides some evidence of a developmental sequence, relating to work with repeating patterns. Children first demonstrate competence in copying patterns; at the next stage they are able to identify patterns; and at a further stage they demonstrate competence in continuing patterns.

Frith (1970) presents additional evidence relating to developmental sequences in work with repeating patterns but in this case across a longer time span. This study reports that children younger than 4 years frequently repeat single elements of a sequence (perseverance); from 4 to 5 years up to 9 years of age, children successfully alternate two distinct elements; and from 9 to 10 years of age, children work successfully with more complex sequences.

Sternberg's Pattern Recognition Study

Sternberg (1974) carried out research to extend the findings of these earlier studies, introducing a more demanding definition of pattern recognition. He worked with children in pre-kindergarten, kindergarten and first grade classes, who were assigned to high and low ability groups, based on teacher's ratings. Sternberg's study includes simple pattern continuation tasks based on colour and pictures, described as 'original learning' tasks. Competence in these tasks is defined as a lower level competence than true 'pattern recognition'. The study also includes pattern continuation tasks, incorporating shifts in a repeating sequence. For example, in an 'intra-dimensional shift', the sequence 'red, blue, red, blue' becomes 'green, yellow, green, yellow'. Sternberg classifies competence in these more complex tasks as 'pattern recognition'. As a further task variation, four different pattern sequences are used (ABAB; ABCABC; AABAAB; ABBABB).

Research Findings

The study findings are that pre-kindergarten children fail to provide evidence of pattern recognition ability as defined by the study. High ability kindergarten children do evidence early pattern recognition skills, performing the reverse shift task where, for example, 'cup, dog, dog, cup, dog, dog,' becomes 'dog, dog, cup, dog, dog, cup.'

The study presents some evidence supporting developmental distinctions in task difficulty. Firstly, the findings indicate a hierarchy of levels in relation to the sequence shift. Secondly, colour is found to be the easiest dimension for children to work with in terms of the stimulus dimensions of tasks. Thirdly, the study provides evidence of developmental distinctions

between sequences in terms of task difficulty. The alternating sequence, ABAB, is identified as the easiest sequence and ABCABC the hardest sequence for children to work with. The study confirms that the number of elements involved in a sequence is critical to task difficulty.

Methodological Issues

As a study of pattern-related abilities in the youngest age group, this research is limited. The assessments fail to discriminate between high and low ability pre-kindergarten groups, suggesting a poor match between assessment tasks and children's levels of cognitive functioning. The assessment tasks are dependent on complex verbal instructions and do not seem well matched to the interests or active learning style of the younger age group. As a result of methodological weaknesses, the negative research findings in relation to the youngest children are limited in their validity.

Rustigian's Pattern Continuation Tasks

A further study (Rustigian 1976) undertaken during this period focuses on a younger age group, 3 to 5 year olds, in pattern continuation tasks. This study presents evidence of a developmental sequence in children's responses to pattern continuation tasks. At the first stage, children make no reference to prior elements in a pattern and their selection of elements appears to be random. Following this, at the second stage, the last element in the repeating pattern is repeated (perseverance). At a third stage, children use different elements from the repeating pattern but without regard for order. This stage is followed by a fourth stage, marked by children's reversal of the given pattern. At the most advanced stage, children are successful in continuing repeating patterns. Children at this level may demonstrate checking behaviours, for example looking back to the start of the pattern.

Threlfall's (1999) study of 3 to 9 year olds confirms one aspect of the Rustigian study. In devising but not in continuing contexts, many of the youngest children in Threlfall's study devise sequences that correspond to Rustigian's second level. They show a tendency to repeat the last element in the sequence. Some older children work in a similar manner.

Task Difficulty

Rustigian's study also considers task difficulty, focusing on developmental distinctions in the dimensions of materials. Findings are that children find tasks involving the physical movement of play materials easier than tasks involving pictorial representation. Additionally, in contrast to the Sternberg study (1974) that identifies colour as the easiest stimulus dimension, Rustigian's findings are that form is an easier dimension for children to work with than colour.

THE PIAGETIAN TRADITION

Piaget and Inhelder

Chapter 1 outlined Piaget's significant influence on the 'new maths,' introduced into primary schools from the late 1960's. However, although many aspects of the mathematical development and logical thinking of young children were investigated in Piaget's wide-ranging research programme, the programme did not include a research focus on repeating patterns.

Just one study, reported by Piaget and Inhelder (1967), focuses on young children copying strings of beads, but not patterned strings. This study presents evidence of significant incremental increases in children's copying ability between 3 and 7 years of age.

Pieraut-Le Bonniec

Working after Piaget but within the Piagetian tradition, Pieraut-Le Bonniec's (1982) study examines development in young children's work with alternating patterns. This study uses a set of increasingly complex pattern-making tasks for children at 3, 4 and 5 years of age, using a sample size of 12 for each age group. The study aims to chart children's hypothesised progress towards 'operatory reversibility', a Piagetian concept. Piaget hypothesised a continuity of development from the rhythmic activity of the young infant to the reversibility of operations that is characteristic of the stage of concrete operations. Pieraut-Le Bonniec's study is shaped by his interest in how young children develop an ability to consider properties of objects as meaningful within a system of relations, for example a repeating pattern.

Three levels of task difficulty

Pieraut-Le Bonniec presents pattern-making tasks at three levels of difficulty. Tasks at the first level are based on an alternating sequence (ABAB). At the second level, tasks are based on an inversion of this alternation (ABAB, BABA). At the most demanding level, tasks are based on a cyclic structure of alternating sequences and their inversions, as below.

ABAB

BABA

ABAB

BABA

Research Findings

Research findings confirm the hypothesised hierarchy of levels. However, in this study, only 4 children from the oldest group fully master the cyclic structure of the checkerboard task. At 4 years, most children copy an alternating structure but do not use it spontaneously. At 5 years, 91% of children use the alternating structure spontaneously.

Pieraut-Le Bonniec's analysis of unsuccessful responses to set tasks provides additional evidence of developmental steps within the hierarchy of levels. At the first level, the level of the

alternating sequence, the first identified step is an active alternation. At this first step, children alternately select white and black cubes but show no interest in the spatial organisation of these cubes. Pieraut-Le Bonniec argues that this behaviour may support development towards the second step, where children arrange objects spatially in an alternating manner. At the third and most advanced step, children create the spatial alternation without a need to select black and white cubes alternately

Pieraut-Le Bonniec's study provides no evidence to support the hypothesised direct transition from the rhythmic actions of an infant to the rhythmic organisation of objects and movements considered necessary for mastery of the alternating structure. The 3 year olds, who are the youngest children in this study, are reported as unsuccessful in first level assessment tasks, evidencing no abilities in copying or devising alternating patterns. The study outlines the typical behaviours of these children, for example piling and stacking materials; surrounding or covering the fixed elements of task apparatus with other materials; and filling empty spaces. These children demonstrate interest in particular spatial arrangements of task materials but not in sequencing materials in relation to material attributes.

Discussion

Pieraut-Le Bonniec (1982) highlights the importance developmentally of his third level, mastery of cyclic organisation, achieved by only a few of the 5 to 6 year olds in the study. He argues that an inversion is not possible unless a child has a mental image of the alternation. It is mastery of the alternation within a cyclic organisation that is considered to evidence the flexible, reversible thinking, characteristic of Piaget's concrete operational stage of development.

REPEATED PATTERNS IN THE NATIONAL CURRICULUM

Chapter 1 detailed National Curriculum expectations for children working with pattern in the Algebra programme of study. Aubrey's (1993) study, examining children's mathematical abilities on entry to a reception class, evidences children's competencies in repeated pattern work linked to the National Curriculum programme of study for Algebra (National Curriculum Council 1991). The sample for this study is a reception class of sixteen 4 to 5 year olds (mean age: 4years 6 months).

The study includes three repeating pattern tasks. The first task is to copy and continue an alternating pattern of red and green blocks; the second task is to copy and continue a pattern of three contrasting plastic coins; and the third task is for children to make their own pattern from a set of objects contrasting in shape and colour.

Research Findings

Aubrey (1993) highlights the relative difficulty experienced by children working on pattern related tasks based on the programme of study for Algebra. The findings show these tasks to be more difficult for children than Level 1 tasks from other areas of the number curriculum. Less than half the group are reported as successful in both copying and continuing simple repeating patterns, although some of the unsuccessful children can either copy or continue a pattern in individual tasks. In the open-ended context, no children are judged to be successful in devising a simple regular pattern.

These findings are similar to those of Pieraut-Le Bonniec (1982). In both studies some 4 year olds copy alternating patterns but children of this age do not devise such patterns spontaneously. Aubrey questions whether, in the context of National Curriculum levels, the Level 1 activities from the programme of study for Algebra best match Level 2, rather than Level 1, number activities.

Methodological Issues

Aubrey's study may underestimate children's abilities in copying, continuing and devising repeating patterns. Aubrey states that assessment tasks were purposefully devised to use "everyday objects and activities familiar to children" (1993, p.31). However, although coins and plastic forms may have been familiar to the children from some earlier play contexts, these may not have been the familiar materials of earlier pattern-making work. For the 14 children in this study with nursery or play group experience, other play materials, for example beads or pegs, may have been more familiar pattern-making materials. Flavell et al (1993) discuss the inconsistencies that can arise from children's responses to different assessment techniques. Additionally, both the Sternberg (1974) and Rustigian (1976) studies highlight the dimensions of task materials as a significant feature of task difficulty in work with repeating patterns.

THE AGAM PROJECT

Reports of the progress of the Agam Project, a large-scale action research project, provide additional evidence relating to the ability of young children to devise repeating patterns (Hershkowitz and Markovits 1992). The youngest children in the study are 3 to 4 year old nursery children, with these children then tracked through to third grade. The curriculum programme for the research project has 36 curriculum units. Children initially are introduced to basic visual concepts, for example shape and size. At a later stage they are introduced to advanced concepts, for example symmetry and ratio. The early teaching units in the programme for 3 and 4 year olds focus on circles and squares. These units are followed by teaching units using circles and squares but focused on repeated pattern-making.

Findings

Hershkowitz and Markovits (1992) report that many project children are successful in identifying, memorising and recalling repeating patterns during their time in nursery. The memorisation and recalling activity is a key feature of the programme and one that has not been used in other reported studies. Project children also create their own repeating patterns. Additional findings are that some 4 year olds go beyond planned teaching activities to create complex 2D patterns incorporating repeating sequences. The findings for 4 year olds contrast with previously reported studies where this age group is unsuccessful in devising tasks (Pieraut-Le Bonniec 1982; Aubrey 1993). Comparing this study with others, however, is problematic because much reported evidence relates to project children who receive systematic instruction in pattern-making.

PATTERN PERCEPTION

In Chapter 1, pattern perception or pattern recognition was identified as a key competency in recent early years mathematics curricula. The potential ambiguity of the term 'recognise' was noted. Pieraut-Le Bonniec (1982) emphasises the importance developmentally of pattern perception or the way that a child sees an alternation, suggesting that a pattern may be seen differently at different stages of development. He concludes that the child's developmentally significant competence in inverting an alternation is dependent upon a particular kind of pattern perception.

This view of pattern perception is paralleled by Sternberg's (1974) emphasis on the importance of the reverse shift and other more complex shifts in the development of what he defines as true 'pattern recognition'. Threlfall (1999) points to the significance developmentally of the child's recognition of the unit of repeat within a repeating pattern. Pattern recognition as identified in these studies is a relatively advanced competence. In terms of a developmental sequence, it follows on from competence in copying, continuing or devising simple repeating patterns.

There are, however, methodological difficulties relating to the assessment of this developmentally significant stage of pattern perception. Assessment in the three reported studies seems to be dependent on the child understanding relatively complex verbal instructions or responding verbally to questioning.

EARLY PATTERNING BEHAVIOURS

3 Year Old Behaviours

A number of the studies reported above have included 3 year olds at the younger end of their age range. Generally, the study findings are that few 3 year olds are successful in

conventional pattern-making tasks. Three year olds appear to have little success with copying, continuing or devising repeating patterns, although Threlfall's (1999) study does report children devising repeated patterns from 3 years 10 months. Indeed, given the difficulties experienced by many of the 4 year olds in Aubrey's (1993) study, the lack of success of 3 year olds is not surprising.

Some studies, including the studies of Sternberg (1974) and Pieraut-Le Bonniec (1982) offer mainly deficit descriptions of the behaviours of 3 year olds in response to assessment tasks. Rustigian (1976) in contrast avoids this approach by analysing the unsuccessful responses of younger children and placing these on an hypothesised developmental pathway to repeated pattern-making. He proposes four stages, outlined earlier in the chapter, leading to competence in repeated pattern-making.

Examination of the early responses reported by Rustigian highlights classification skills as a likely precursor of repeated pattern-making competencies. This view is further supported by Simon's (1974) review of studies examining pattern from an information-processing perspective. Simon argues that pattern descriptions in the many coding theories reviewed all incorporate the relations of "same" and "next" between elements.

Classifying behaviour may represent an early stage in a developmental pathway towards repeated pattern-making. Therefore, the research in this area is now reviewed.

Classification Studies

Inhelder and Piaget

Studies by Inhelder and Piaget investigating young children's use of concepts in classification tasks are described by Meadows (1993). Assessment tasks, making use of blocks varying in both shape and colour, assess children's skills in sorting blocks into discrete sets. Inhelder and Piaget report how, at the earliest stage, children enjoy arranging blocks spatially in 'figural collections' but do not classify blocks. This evidence relating to young children's early interest in spatial arrangements matches findings for 3 year olds in the Pieraut-Le Bonniec (1982) study. Following this earliest stage of development, children began to sort objects by particular criteria. However, sorting is not sustained and children frequently change the criteria. At a later stage, children sustain their sorting until all objects have been classified in terms of the chosen criteria.

Vygotsky

Vygotsky's classification studies, described by Meadows (1993), use wooden blocks varying on the dimensions of shape, colour, height and area. Findings relating to the development of classification skills are similar to those of Inhelder and Piaget. Both sets of studies conclude that the ability of pre-school children to form and use concepts in classification

tasks is limited and that young children are unable to keep different categories in mind simultaneously.

Vygotsky's study, in addition, highlights differences relating to the dimensions of play materials. Shape and colour are identified as the most salient dimensions. The younger children use these dimensions exclusively.

Later Studies

Later studies, reported by Meadows (1993), have been critical of some of these findings, presenting evidence of rudimentary classification skills in very young children, including infants as young as 12 months. These later studies, rejecting attribute based sorting tasks of the kind used by Piaget and Vygotsky, use objects more salient in the young child's experience. Sugarman, tracking the development of classification skills from the first year of life has carried out a number of studies (Sugarman 1982; Sugarman 1983).

Sugarman (1982) argues that earlier studies underestimate the increasingly complex classification skills that children develop over the first three years of life. She reports a major shift in children's thinking about objects, taking place at around 2½ years of age. This shift parallels the major changes in the way that children use language to represent experience taking place at around this time.

The supporting evidence for this theory comes firstly, from observations of children's manipulations and arrangements of objects and secondly, from children's verbal descriptions accompanying play. Study findings show children, from about 2 years of age, explicitly referring to relations of similarity and difference. Sugarman (1983 p. 173) also presents verbal evidence of children, from 2½ years, keeping in mind two distinct comparisons based on different criteria. One child, for example, manipulating objects from a collection, comments, "There's the doll, little one. There's the doll, big one." Sugarman argues that these children are successful in coordinating comparisons of similarity and difference. These findings are seen to challenge the conclusions of Piaget and Vygotsky.

THEORETICAL ACCOUNTS OF REPEATED PATTERN-MAKING

Many of the studies of young children making repeated patterns have been primarily empirical studies, aimed at defining developmental sequences and establishing developmental distinctions in relation to task difficulty. Most have been framed within a context of theory, although this field is less dominated than other fields of mathematical learning by Piagetian theory and the varied theoretical responses to this. Several different theories have been used in framing the research studies outlined above, as well as in interpreting results, and these are now considered.

The Piagetian Tradition

Pieraut Le-Bonniec

The Pieraut Le-Bonniec study (1983) is shaped by Piagetian stage theory. This theory hypothesises a fundamental cognitive restructuring taking place at each stage of development. The period from 2 to 7 years of age, the pre-operational stage, is partly characterized in terms of the lack of simultaneous reversibility in the child's thinking (Goswami 1998). Pieraut Le-Bonniec selects pattern-making tasks to highlight developments in the child's thinking between the pre-operational stage and the beginning of the stage of concrete operations. Success in second and third level tasks in this study is seen to depend on the reversible thinking that is characteristic of the stage of concrete operations. The conclusion of the study is that:

... the progressive mastery of situations implying alternations, inversions of the alternation, and cycles must indeed constitute an important phase in the construction of different forms of reversibility in children between 3 and 6 years of age. (Pieraut Le-Bonniec 1982, p.262)

In terms of Piagetian theory, achievement of the more advanced forms of pattern recognition or pattern-making competence parallels the achievement of conservation in the area of number.

Sugarman

Sugarman's (1983) study of the development of early classification skills is similarly developed within a framework of Piagetian theory but it focuses on cognitive development within Piaget's sensorimotor and pre-operational stages. This study challenges the detail of Piaget's findings in relation to the classification skills of children from 1 to 3 years. However, it does not challenge the underlying principles of Piagetian theory.

From the 1970's onwards, many research studies have challenged Piaget's findings relating to children in the 2 to 6 year old age group. Case (1985 p.149) for example, has outlined reservations about this aspect of Piaget's work, echoing the views of Sugarman, "In effect, therefore, there is a missing link in Piaget's work. The exact nature of the transition from sensorimotor to logical thought is not clear." Case argues that Piaget's account of this period is based on limited data and that Piaget fails to describe the sub-stages that children pass through in as precise a way as he details sub-stages for earlier and later stages.

Sugarman's study (1983), using a Piagetian framework, provides rich data relating to the development of children's classification skills in the first half of the pre-operational period and it describes the sub-stages through which children pass in a detailed manner.

Cognitive Science

Information-processing accounts of behaviour have focused on how information is handled in the context of problem-solving, for example how information is "selected, represented, stored, retrieved, transformed" (Meadows 1993, p.212).

A cluster of empirical studies in the 1970's, investigating the responses of young children to tasks with repeated patterns, are set against the background of newly developing cognitive science.

Measures of Pattern Complexity

Theorists in the field of cognitive science began by studying thinking in adults but the field expanded from the 1970's onwards to include studies of thinking in children. However, the cluster of studies in the 1960's and early 1970's relating to patterned sequences did not discriminate between the thinking of adults and children. Threlfall (1999), reviewing these studies, highlights a common objective, to establish a hierarchy of sequencing tasks, defined in terms of theoretical task difficulty, and to compare theoretical difficulty ratings with ratings in actual performance. Vitz and Todd's study, for example, establishes "a measure of pattern complexity", defined as "the total amount of uncertainty evaluated in processing the stimulus sequence" (Vitz and Todd 1969, p.433).

A Review of Coding Studies

Simon reviews a large number of coding studies, carried out from the late 1950's onwards and developed "to explain how human subjects process patterned sequences of symbols" (1972, p.369) The studies under review include sequences made up of digits, letters, geometric figures, musical and others elements. Studies include pattern reproduction tasks, pattern continuation tasks and tasks where subjects are asked to rank sequences in terms of perceived complexity. Simon concludes that differences between the theories are in fact superficial. All theories share some key elements. Firstly most theories hypothesise a language or notation to describe patterns and these pattern descriptions all incorporate the relations of 'same' and 'next' between the pattern elements. Secondly, the theories all hypothesise one or more common processes, for example storing pattern descriptions.

Recent Developments in Cognitive Science

Recent theorists working within the tradition of cognitive science provide the background for Aubrey's (1993) study of the mathematical knowledge and competencies of reception class entrants. Key aspects of Putnam's review of the major themes of recent approaches to mathematical learning guide both the purposes and the methodology of Aubrey's study (Putnam et al. 1990).

These recent approaches to the study of mathematical thinking contrast with the approaches of earlier studies. Early studies focus in a detailed way on specific pattern-related tasks, often undertaken by adults, with research carried out in laboratory settings. Many recent theorists have focused specifically on the ways that young children develop mathematical knowledge, studying children in the ecologically valid contexts of home and school.

Aubrey considers the following themes of recent cognitive theory to be significant in the framing of her study:

1. Understanding as connections among types of knowledge

A key focus for Aubrey's study is "the linking of the formal, symbolic mathematics of school to the knowledge children develop out of school" (1993, p.28).

2. Understanding as representation

The study is concerned to highlight ways that children can be supported in moving forwards from "earlier and more idiosyncratic personal systems" towards shared, formal mathematical representations (1993, p.29).

3. Learning as active construction of knowledge

A key aim for Aubrey's study is to consider how the child's existing knowledge impacts on current learning.

4. Understanding as situated cognition

The methodology of Aubrey's study, with children assessed "in the context of known situations and authentic activities," is shaped by the recognition that children's mathematical knowledge is built up through their everyday experience of a physical and social world (1993, p.30).

Although not solely focused on young children working with pattern, Aubrey's study shows how these broad themes of cognitive theory relate to all aspects of the young child's mathematical learning.

Bruner

Bruner's early theoretical work on modes of thinking and learning provides the theoretical context for the development of pattern-related tasks in Rustigian's (1976) study of the development of pattern recognition.

Wood (1988) provides a summary of Bruner's theoretical account of contrasting modes of knowing. Bruner proposes three contrasting modes for knowledge of the world to be represented. The first mode, the enactive mode involves an active engagement with experience, for example through the use of concrete apparatus to express knowledge. The second mode, the iconic mode involves the depiction of experience through the use of a medium of one to one correspondence, for example a picture or visual image. The third mode, the symbolic mode involves more abstract forms, for example languages or mathematical symbols, in the representation of knowledge. Bruner's theory, like that of Piaget, identifies children's growing ability to deal with abstractions as a significant feature of cognitive development. His three modes represent three levels of increasing abstraction. However, they do not represent three distinct stages in thinking. Bruner argues that, with appropriate instruction, symbolic modes can also be made accessible to young children.

Rustigian (1976) uses Bruner's theoretical framework to devise linear pattern

tasks in three contrasting forms, concrete, pictorial and abstract. In this study, children are most successful when working with concrete materials in the enactive mode.

REPEATING PATTERNS: SUMMARY AND DISCUSSION

Children's Relative Skills in Copying, Continuing and Devising patterns

Three Year Olds

Since the 1970's, a small number of the studies focusing on young children copying, continuing and devising repeating patterns have included 3 year olds. The findings of these studies are that few 3 year olds are successful in copying, continuing or devising tasks.

Four, Five and Six year olds

A slightly larger group of studies have reported on the abilities of 4 and 5 year olds in work with repeated patterns. One study has also considered young children's skills in memorising and recalling repeated patterns (Hershkowitz and Markovits 1992). The findings of these studies are that, although many children can copy and continue repeated patterns by 5 years, these competencies are not secure for all children. Many children at the start of their reception year in Aubrey's study (1993) either copy or continue repeating patterns but cannot do both. Using Sternberg's more demanding definition of 'pattern recognition', however, only high ability 5 year olds are successful in advanced pattern continuation tasks.

Turning to young children's competencies in devising patterns, study findings (Pieraut Le-Bonniec 1982; Aubrey 1993) are that 4 year olds are unlikely to be successful in devising contexts. At 5 years, however, 91% of children in the Pieraut Le-Bonniec study devise an alternating pattern with beads. Findings from the Agam Project (Hershkowitz and Markovits 1992) are more positive in relation to the achievements of 4 year olds, with project 4 year olds successfully devising repeated patterns.

Developmental Pathways to Repeated Pattern-Making?

A small number of studies have analysed the unsuccessful responses of younger and some older children to pattern assessment tasks. These studies report common behaviours or common sequences of behaviour that may precede repeated pattern-making. Rustigian's (1976) study provides the most detailed account of a developmental pathway to repeated pattern-making. The earliest organised responses of the children in this study focus on relationships of similarity, with children repeating a single element of the given sequence. Frith (1970) and Threlfall (1999) report similar responses. At a second stage, children's responses focus on relationships of similarity and difference.

The competencies of Rustigian's youngest children may relate to the competencies of the 2 and 3 year olds studied by Sugarman (1983). Sugarman's children are similarly

preoccupied with relationships of similarity and difference as they handle and arrange familiar objects and as they talk about them.

The findings of other studies evidence developmental sequences amongst older children. Cromie's findings for 4 to 7 year olds indicate a developmental sequence from pattern copying to pattern identification and then on to pattern continuing. In Aubrey's (1993) study, there is no evidence of a developmental distinction between copying and continuing tasks. However, there is evidence identifying devising as a more advanced competence than either copying or continuing. Other studies (Frith 1970; Sternberg 1974; Pieraut-Le Bonniec 1982) propose a sequence leading from work with simple alternating patterns, from 4 to 5 years of age, to work with more complex patterns. The studies, however, define complex patterns in different ways. Task difficulty in the Sternberg study relates to the number of elements in the pattern and to shifts within sequences. In the Pieraut-Le Bonniec study, the developmental pathway is from alternating patterns, to an inversion of an alternation and then on to a cyclic structure.

Dimensions of Task Materials

A small number of studies focus on developmental distinctions in relation to task materials. In pattern recognition tasks in the Sternberg study (1974), colour is identified as the easiest dimension. Rustigian (1976), using Bruner's theoretical framework, finds that children are most successful when working with concrete materials in the enactive mode. Additionally, this study finds that form is an easier dimension for children to work with than colour, in contrast to Sternberg's study.

Sugarman (1982, 1983) emphasises the importance of using objects that are interesting and familiar to young children in assessment contexts, to prevent underestimation of children's competencies.

Pattern Perception

Several studies (Sternberg 1974; Pieraut-Le Bonniec 1982; Threlfall 1999) identify pattern recognition as a relatively advanced and developmentally significant competence. These studies propose that pattern recognition follows on from competence in copying, continuing and devising simple repeating patterns.

Theoretical Accounts of Repeated Pattern-making

Research relating to repeating patterns and early patterning behaviours has been undertaken from the perspective of Piagetian theory (Pieraut-Le Bonniec 1982; Sugarman 1982) and from the perspective of cognitive science (Simon 1972; Aubrey 1993). Work in the Piagetian tradition (Pieraut-Le Bonniec 1982) has identified young children's work with repeating patterns as developmentally significant in terms of the child's transition from pre-operational thinking to the flexible and reversible thinking that is characteristic of the stage of

concrete operations. Simon's (1972) review of sequencing and pattern organisation studies from an information processing perspective highlights the importance of relations of 'same' and 'next' in descriptions of pattern descriptions. Theoretical perspectives from cognitive science that support an understanding of the importance developmentally of young children's informal mathematical learning shape Aubrey's (1993) work. These perspectives have strong methodological implications, but do not focus on repeating patterns specifically.

DIRECTIONS FOR RESEARCH

There is a large and wide-ranging body of research evidence relating to young children's developing knowledge, understanding and skills in the area of number, developed over the decades since the 1960's (Thompson 1997). In comparison, the research evidence relating to young children's developing knowledge, understanding and skills in the area of repeating patterns is limited. As a research base for approaches to repeating patterns in the foundation stage curriculum, there are significant gaps and areas of weakness. In this section, examination of these gaps and areas of weakness contributes to identification of a broad area of focus for examination in the main study.

The competencies of 3,4 and 5 year olds

The limited research findings relating to 3 year olds are mainly negative and there are some contradictions in the research evidence relating to 4 year olds. Given the evidence of variability in performance in other aspects of cognition, resulting from small variations in task presentations (Meadows 1993), these findings are worthy of further review. Threlfall (1999) reports some successful pattern-making by 3 year olds at the older end of the age range. Perhaps significantly, these positive results relate to children working in the naturalistic setting of their nursery class, with a familiar adult presenting the task as an every day play activity.

The research base relating to 5 year olds, presents some positive evidence of children's competencies in copying, continuing and devising tasks, particularly in tasks with alternating patterns. This research base supports the inclusion of copying, continuing and devising activities in National Numeracy Strategy guidance (DFEE 2000). However, it is not a broad research base and this may account for low expectations of repeating pattern competencies in the pattern-related early learning goal and in the guidance sections of Curriculum Guidance for the Foundation Stage (DFEE 2000).

No studies to date focus on the skills of 3, 4 and 5 year olds in talking about repeating patterns, although the ability to talk about and recognise patterns is included in the pattern related foundation stage goal. Research evidence relating to pattern recognition is mainly focused on a relatively advanced stage of pattern-making competence. Young children's skills in

talking about repeating patterns and the nature of pattern recognition amongst 3 to 5 year olds is an area warranting further examination.

Developmental pathways

The research base for the stepping stones to repeated pattern work in the foundation stage curriculum guidance is also limited. There is just one example (Rustigian 1976) of an hypothesised developmental pathway that starts with the seemingly random early responses of 3 year olds and leads on to success in pattern continuation tasks. Rustigian's (1976) approach to the analysis of responses of 3 to 5 year olds in pattern continuation tasks is a potentially productive direction for future research. Sugarman's (1982 and 1983) development of Piagetian theory may be important to further analysis of findings in this area. Additionally, it would be useful to test a hypothesised extension of Rustigian's developmental pathway, recognising the qualitative data from the Agam program relating to the achievements of 4 year olds in devising complex repeating patterns (Hershkowitz and Markovits 1992). Finally, it would be useful to consider a developmental pathway in the context of pattern copying and devising activities, as well as pattern continuation activities.

In considering a developmental pathway towards repeated pattern-making, it seems important to bear in mind that there may be "alternative paths to the same outcome", as shown by some recent work in the Piagetian tradition (Meadows 1993, p.211). This possibility has not been considered by the research studies undertaken to date.

Longitudinal studies have been important in establishing developmental sequences in other areas of cognition, for example in the area of language development (Brown 1973). No longitudinal studies have been undertaken in this area of mathematics and a longitudinal study would be a valuable strand within the main study.

Individual differences

Longitudinal studies can be important in highlighting individual differences as well as commonalities in development. Individual differences have not been discussed in this section of the literature review because there is no research literature relating to individual differences and repeated patterns. There are, however, research findings (Nickson 2000) relating to gender differences in algebraic problem-solving amongst secondary age students. Findings for this older age group, in an area of maths that may be linked to linear repeated pattern-making (Threlfall 1999), are complex and highlight this as an important area for further review.

The dimensions of task materials

Finally, some of the studies reviewed have focused on developmental distinctions in terms of the dimensions of task materials. Rustigian's (1976) study highlights concrete materials, supporting work in the enactive mode, as the most accessible materials for young children. Other

findings, relating to developmental distinctions between shape and form, are contradictory. To support teaching and learning in the foundation stage, it would be useful to extend knowledge about the impact of the different dimensions of play materials.

In conclusion, there are some interesting findings but many gaps and areas of weakness in the research base underpinning approaches to repeating patterns in the foundation stage curriculum. A number of areas for further review have been identified. These are revisited in the conclusions to this chapter and also carried forward into the first pilot study, as a part of the process of defining research questions for the main study.

2D SHAPES AND SPATIAL PATTERNS

In the first part of this chapter, the research literature relating to young children's knowledge, understanding and skills in the area of repeating pattern was reviewed. In this, the second part of the chapter, a review is undertaken of the research literature relating to young children's knowledge, understanding and skills in the area of 2D shape and spatial patterns.

The review of the research literature begins with three empirical studies of spatial pattern-making in the pre-school and early years of primary education. Two studies focus on children's work with mark-making media. The third study examines children's work with a wider range of media. The chapter moves on to a consideration of studies focused on developmental pathways to both spatial pattern-making and early representational art work. Following this, the literature relating to early spatial organisation in, for example, shape drawing, is examined. Finally, theoretical accounts of the cognitive processes involved in identifying and making 2D shapes and patterns are reviewed.

This second section of the chapter continues with a summary of findings and the identification of gaps and areas of relative weakness in the research base relating to young children's competencies in work with spatial patterns. Evaluation supports further delineation of a broad area of focus to be taken forward into the first pilot study, where the process of defining precise research questions for the main study is completed.

MAKING SPATIAL PATTERNS

In the late 1960's the Nuffield Mathematics Project introduced a new focus on spatial pattern-making into the mathematics curriculum for the youngest children in schools. Following this new curriculum focus on spatial pattern-making, there has been little research focus on this aspect of young children's mathematical learning. However, a small number of studies have focused on the ways that young children in their paintings and drawings spontaneously combine selections of lines, other marks, and/or shapes to make spatial patterns. With the exception of one set of studies (Booth 1981), these studies present patterned configurations as a step in

children's development towards a representational style of art. A further study (Gura 1992) examines patterned configurations from a mathematical perspective, as one strand of children's spontaneous play with wooden blocks.

Rhoda Kellogg

Many patterned configurations are identified in Kellogg's (1969) study. This study identifies 20 early scribbles from a large collection of drawings that children use as the building blocks of simple and more complex geometric forms. Kellogg categorises the complex geometric forms as combines, aggregates, mandalas and sun schemas. Children's creation of these increasingly complex patterns is viewed as steps on a developmental pathway towards early representational art. Kellogg's research methodology and some findings have been challenged (Cox 1992). However, some of the patterned configurations Kellogg identifies in young children's art match configurations identified in more recent studies (Booth 1981; Fenson 1985; Athey 1990).

Drora Booth

Booth (1981) reports on the pattern painting of a class of 5 and 6 year olds in a study undertaken from a mathematical perspective. The study describes how children, over a period of a year, were encouraged to work spontaneously with paint and brushes, without pressure to paint objects or people. Booth argues that educators generally encourage representational rather than pattern making work in young children's paintings. However, her analysis of paintings collected over the year shows how, with this emphasis removed, children spontaneously combine lines and sometimes dots, to create increasingly complex patterns. Booth (1981, p.226) classifies children's patterns as firstly, patterns "arising from a systematic repetition of an element" and secondly, "patterns arising from the division of a plane."

The systematic repetition of elements

Examining the first class of patterns, the study presents evidence of children commonly devising simple translation patterns and two dimensional translation patterns. Some children also devise reflective translation patterns. These reflective patterns include from sides to centre patterns and from corners to centre patterns. Again, less frequently, children devise patterns based on rotation about a point.

Division of a plane

Turning to the second class of patterns, there are findings of children commonly making simple patterns by dividing the plane with two diagonals, two medians or a combination of these. Sometimes the resulting segments are filled with one fold or two fold reflective patterning. Booth exemplifies some less common and more complex patterns based on these divisions of

the plane. Both shape and colour are often used as elements of reflective symmetry in this second class of patterns. Some of the configurations identified by Booth match patterned configurations identified by Kellogg (1969).

The Froebel Early Education Project

The early translation patterns, identified by Kellogg and Booth, have also been found in the work of children at the younger end of the age range, 3 and 4 year olds in a nursery class. Athey (1990) identifies twenty-four distinctive marks, sub-divided as straight lines and curves. Amongst the fourteen marks classified as straight lines, two marks match forms identified by Kellogg and Booth. These are named 'straight parallel lines' and 'stripes'. Athey's 'grid' also matches the 'vertical and horizontal' grid identified by Booth, although most of Athey's examples are rough forms of this grid. In addition, Athey identifies a number of examples of children coordinating marks in the core and radial configuration, a pattern identified by Kellogg (1969) but found to occur infrequently in Booth's (1981) study of 5 and 6 year olds.

Athey (1990) argues that young children make use of the forms used in drawing and painting in their work with 3D play materials. However, although her study provides reports of children making linear arrangements with a variety of play materials, there are few unambiguous examples of children using play materials to create the patterned configurations discussed above.

Athey's study is primarily focused on the ways that children use graphic and 3D media to represent experiences and so provides only limited insights into children's interest in these forms as abstract patterns.

DEVELOPMENTAL PATHWAYS TO SPATIAL PATTERN-MAKING

Several studies hypothesise developmental pathways, incorporating a wide view of children's knowledge, understanding and skills relating to shape and space. Two accounts of development in this area are discussed in a later section outlining the major, theoretical contributions to the field. These are firstly, the theoretical work of Piaget and secondly, the work of the Van Hiele. These theories are based primarily on the analysis of data arising from formal assessment tasks.

In addition to the major theoretical accounts of development through childhood, a small number of researchers have focused on the early years of childhood. Following analysis of children's spontaneous work with mark-making media, they have proposed developmental pathways in spatial organisation.

Rhoda Kellogg

Kellogg (1969) presents a detailed developmental sequence, partially outlined above, and one that is specifically focused on early development in art. Kellogg's account is generalized

from a very large collection of childrens' drawings. There is no indication in Kellogg's writing that the hypothesised pathway, incorporating increasingly complex patterns at stages 2 to 4, is rooted in case studies of individual children followed over time. Cox (1992, p.15) describes Kellogg's account of development as "neat and rather compelling", although flawed in so far as later studies fail to confirm some of the detail of the pathway. Cox's review of subsequent research in this area confirms that some children do go through a period of experimentation with shapes and patterns. However, this is not universal and children's progress does not seem to be as orderly as Kellogg's account suggests. Two more recent studies, one from the field of art education (Fenson 1985) and one from the field of mathematics education (Booth 1981), do propose developmental pathways, with analysis rooted in the development of individual children. Each study in some way confirms and challenges aspects of Kellogg's hypothesised developmental pathway.

A Longitudinal Study

Fenson's (1985) longitudinal study focuses on drawing development in one child, his son. The study is based on 1,200 examples of the child's graphic work, collected between 3 years 5 months and 7 years of age. Although the main focus of Fenson's study, like that of Kellogg, is on development towards representational drawing skills, the study has a useful contribution to make to an understanding of the development of 2D pattern-making skills.

Drawing Units

The child's reported scribbling period lasted just a few weeks. Fenson describes how his son then set out on an extended period of exploration of both geometric forms and compositional strategies. The geometric forms, termed 'drawing units', include rectangles, circles and ovals, matching some of earliest forms in Kellogg's proposed sequence. Fenson describes how particular forms were explored repeatedly over a single day or several days.

Compositional Strategies

Fenson describes how his son, during the same period, developed some key compositional strategies. One reported strategy is 'enclosure'. Fenson describes how the child drew an enclosing line and placed additional elements inside this. Another reported compositional strategy is 'partitioning'. In this case, Fenson describes how the child divided an enclosure through the use of horizontal and vertical lines. The products of both of these compositional strategies parallel graphic forms in the Athey and Kellogg studies. Another reported compositional strategy is 'filling in', where the child fills enclosed forms with colour. Fenson identifies a final strategy, 'chunking', where similar forms are placed in succession. These last two strategies do not match features described in either the Athey or Kellogg studies.

Building blocks of picture construction

Fenson describes the 'drawing units' and 'compositional strategies' used by his son as building blocks for use in picture construction. Like Kellogg, he argues that the child's first representational drawings are constructed from the simple geometric forms that are developed during an earlier period of drawing development. Fenson describes how from 5 years 5 months his son moves on to explore a new style of drawing, with an increased use of outlined forms and a gradual rejection of the geometric forms of the earlier period.

Methodological Issues

This interesting study is inevitably limited by its focus on only one child. There is a possibility that the 'chunking' and 'filling in' strategies used by this child are idiosyncratic strategies, shared by few children, and therefore not identified in other studies. Additionally, it is not possible to know whether Fenson as a parent encouraged his son's progression towards representational rather than abstract drawing, in a way paralleling that of the teacher-researcher in the Froebel Early Education Project. It is possible that, in a different context, the building blocks of picture construction might also be the building blocks of 2D pattern-making. The strength of this possibility is evidenced by the study reviewed below.

Development in Pattern Painting

In Booth's study (1984), analysis of the spontaneous pattern painting of 5 and 6 year olds leads to an hypothesised developmental pathway towards complex 2D pattern-making. Working within a context of Piagetian theory, Booth proposes a three stage model of development. Children begin at a 'scribble stage', progress to a 'topology stage' and move on to a 'geometric pattern stage'.

The Scribble Stage

During the initial 'scribble stage', children gain increasing control over the painting tools and materials through practice with a scribble stroke. Characteristically, they start painting in the middle of the page, pile marks on top of each other and leave the remaining area blank.

The Topology Stage

During the 'topology stage', children begin to show classificatory behaviour through the attention given to the separation of colours in their paintings. Spatial behaviour is also evident in the attention given to filling available spaces with patches of colour placed next to each other. With the increasing coordination of visual and motor actions necessary to achieve these effects, the child's scribble like painting stroke is gradually transformed into single strokes. The new strategies of Booth's topology stage have parallels in the 'filling in' and 'chunking' strategies identified in the Fenson (1985) study.

The Geometric Pattern Stage

This stage is characterised by children's sustained use of a one-directional line stroke or dot stroke. Once the line stroke is established, children focus attention on painting shapes. Interest in colour and 'filling in' sometimes wanes during this period. As children gain experience, lines, dots and simple shapes come to function as the building blocks of pattern-making.

Booth outlines significant development in 2D pattern-making taking place within this 'geometric pattern stage'. Children's early patterns are translation patterns, with a single element, typically a line, repeated across the page. Developmentally, children go on to repeat elements in increasingly complex ways. Two-dimensional translation patterns, for example, follow simple translation patterns. At a more advanced stage, children progress to repeating elements in reflection patterns, with reflections around horizontal and vertical lines appearing prior to reflections around diagonal lines. Developmentally rotation patterns follow on from reflections. However, few children are reported as devising rotation patterns during this study.

Comparison With Other Studies

Key aspects of Booth's account are confirmed by other studies. The developmental order for transformations, outlined by Booth (translations, reflections and then rotations) is confirmed by the results of other studies (Dickson et al. 1984).

Booth's account also emphasises the rule-based nature of children's behaviour. She notes that some of the rules used by children in spontaneous work match those noted in earlier assessment based research. For example, in many patterns, children begin painting at or near to the upper left corner of the paper. Children follow the left to right and top to bottom rules noted by Goodnow (1977) in relation to studies of children's drawing strategies.

Block Play

Few creative or mathematical materials used in the early years have been studied in as much detail as mark-making media. Block play, however, has been the focus of a number of studies from the 1920's onwards.

Piagetian Studies

Blocks have been used in two Piagetian studies of cognitive development with children from 3 to 7 years. Goodson (1982) focuses on the hierarchical complexity of children's constructions, in particular on the construction of arches. Reifel and Greenfield (1982) focus on children's symbolic and spontaneous use of blocks in a structured play context. There is a focus on spatial organisation but no explicit focus on pattern in these studies.

Goodson's findings are that, in reproduction tasks, most children can build an arch or a set of multiple arches in a pile or a row by around 3 years. Following on from children's early

stacked constructions, more complex arch constructions in two dimensions develop from 4 years of age. Reifel and Greenfield's findings relating to the spatial competencies of children in spontaneous block play are very different. Most 4 year olds work at the earliest hypothesised Level O in terms of hierarchical integration, placing blocks singly or in simple linear arrangements.

As background to their studies, Goodson and also Reifel and Greenfield present useful summaries of the early stages of development in children's block play, drawing on the research of Gessell, Guanella and Johnson, from the 1920's to 1940's. These studies demonstrate how children below 2 years typically play in manipulative rather than constructive ways with blocks. In first constructions, blocks are placed in pairs. This is followed by a stage of construction, first with extended vertical placement of blocks and then extended horizontal placement, resulting in rows of blocks. Extension in two dimensions follows, for example in walls of blocks, and also in flat extensions, for example floors of blocks. At this stage, children may fill spaces with blocks or create spaces through the construction of enclosures. A series of enclosed areas may be constructed. Bridges and a variety of more complex structures follow, with forms combined and elaborated in increasingly complex ways.

There are parallels here, in terms of development in motor control and spatial organisation, to reported developmental features in studies of mark-making (Booth 1981; Fenson 1985; Athey 1990). There seems to be a shared exploratory stage, where materials are manipulated and children develop motor control. The linear stage of spatial organisation has parallels in early line drawing. Following this, the development of simple 2D forms has parallels in the drawing units identified by Fenson (1985). Finally there is a shared stage, where simple geometric forms are increasingly combined in more complex configurations.

The Froebel Blockplay Research Group

Findings of an action research project (Gura 1992) include qualitative data exemplifying young children's pattern-making work with 3D materials in play with wood blocks. The study identifies three groups of children. One group of children, preoccupied with spatial configurations and patterns, are identified as 'patterners' or 'visualisers'; a second group, preoccupied with the use of blocks as story props, is identified as 'dramatists'; and a third group of children combines these play styles. The focus on pattern is a relatively minor theme within the study.

The study reports on a number of repeated subroutines observed during the early stages of block play, confirming earlier studies. For example, children sort and match blocks; they connect blocks; they place blocks to form parallel lines, right angles and enclosures; and they fill spaces with blocks. Again, over time children coordinate these sub-routines, making increasingly complex constructions. The study reports that some children demonstrate an awareness of symmetry in their more complex configurations. However, as a result of the research project

methodology, the findings in relation to developmental sequences, including the development of patterning, remains suggestive.

EARLY SPATIAL ORGANISATION

Reported studies (Kellogg 1969; Fenson 1985; Booth 1981), focusing on development towards spatial pattern-making with graphic and paint media, identify a common sequence of early stages. In the section that follows, a range of studies is reviewed, focusing in a more detailed way on the earliest stages in children's developing control of media and spatial organisation. Some studies focus primarily on children's development from the perspective of mathematics and some from the perspective of art. Some studies report children's responses to formal assessment tasks, while others focus on children's spontaneous work.

Making Lines

Copying Lines

Cox (1992) reports that between 2 and 3 years, young children develop the ability to copy vertical, circular and horizontal strokes, as well as the diagonal strokes of a cross. This competence, however, is initially limited to contexts where the child has observed an adult making these marks. The skills of copying from a ready-drawn model develop more slowly, with small variations in context, for example the frame of reference for drawing, sometimes having a significant effect on performance.

Drawing Lines

There is conflicting research evidence relating to children's spontaneous drawing of lines, particularly the age for the first appearance of spontaneous drawing. Kellogg's (1969) analysis of a large collection of young children's drawings led her to propose an early repertoire of 20 scribbles, including single vertical, horizontal and diagonal lines. Some of Kellogg's key findings have been challenged by other studies, for example Golomb's study, outlined by Cox (1992). Golomb's study fails to identify many of Kellogg's discrete scribbles, including single lines, in early drawings.

Working with 5 and 6 year olds, Booth (1980 p.123) reports how some children begin to paint controlled single lines. Early line painting develops from the "oscillating or circular scribble stroke" characteristic of an earlier stage of painting. It is possible that line painting is a relatively late development in this study because children had limited previous experience with paint. Additionally, paint may be more difficult for young children to control than, for example, pencils, marker pens or crayons.

Despite some variations in the research evidence reviewed, it does seem likely that many children draw lines spontaneously by 3 or 4 years of age. Cox's (1992) review of a range of

studies shows that most young children draw their first human figures by 3 or 4 years of age and that, in these early figures, they use lines to represent arms and/or legs.

Constructing Lines

While many 2 and 3 year olds are developing early skills in copying and drawing lines, some also “make lines with any objects that can be aligned” (Athey 1990, p.90). Athey describes children making linear arrangements of objects as a common feature of their play. For example, she describes how Kamal made linear arrangements of objects in several different contexts, from just 2 years of age. These observations precede observations of Kamal drawing and painting lines at 3 years of age. However, Athey’s research study does not focus on developmental sequences at this level of detail and so it cannot confirm this as a typical sequence of development.

Making Shapes

Copying Shapes

Cox (1992) outlines how, from 3 years of age, children’s skills in copying shapes begin to develop. The circle is mastered first. Copying skills are then extended slowly, with a cross mastered by 4 years, a square by 4 years 6 months and a triangle by 5 years. The drawing of diamonds is not mastered until 7 years of age. This sequence of development reflects the relative difficulty that young children experience in drawing oblique lines. Triangles and diamonds, the shapes incorporating oblique lines, prove to be the more difficult shapes copy.

Spontaneous Shape Drawing

Kellogg’s analysis of children’s drawings identifies a ‘single crossed circle’ and an ‘imperfect circle’ amongst the 20 basic scribbles (Cox 1992, p.14). A rough circle is an early appearing enclosed shape in spontaneous drawings in Athey’s (1990) study. She reports several observations of 2 and 3 year olds drawing circles to represent circular objects, including a bubble, a hat and a puddle. Cox’s (1992) review of a range of studies also shows many young children drawing their first human figures at 3 years and making use of rough circles as well as lines.

Kellogg’s early appearing forms include rectangles and triangles as well as circles but there is little confirming research evidence. Athey’s (1990) study, however, reports on several children who struggle to master the spontaneous drawing of rectangles. With one younger exception, successful drawers of rectangles and triangles in this study are four year olds.

Rules for Shape Drawing

Goodnow (1977), investigating the process by which children copy and draw shapes, has outlined some common ‘rules’, followed by many children when drawing both shapes and

letters. Rules are consistent across several cultures and are commonly adopted before formal tuition in writing begins.

For example, preschoolers show a strong preference for top to bottom order in their drawings of both people and shapes. Goodnow found that 80% of the 4 year olds in a nursery class drew a cross, starting with the vertical line from top to bottom and proceeding to the horizontal line. She suggests that such self-initiated rules may be supportive for children in the initial stages of skill acquisition.

Constructing Shapes

Some studies evidence young children constructing as opposed to drawing 2D shapes. Connolly's findings, reported in Cox (1992), are that 5 and 6 year olds make more accurate copies of shapes using matchsticks than when drawing. Dickson et al. (1984) review a study by Fuson and Murray with similar findings that includes younger children. The findings are that children are more successful when constructing shapes with sticks than when drawing shapes. Most 3½ year olds, for example, are successful in constructing a square with sticks.

SHAPE AND PATTERN PERCEPTION

A range of studies has examined young children's developing abilities in shape perception. A smaller number of studies relate to young children's perception of spatial patterns.

Recognising Shapes

Cox's (1992) review of studies evidences abilities in shape perception developing from early infancy. Early progress in shape perception continues and, by 2 years, 70% of children are able to place a circle, square and triangle in a three-hole form board in the context of a Stanford-Binet intelligence test (Athey 1990). By 3½ years of age, children can identify four shapes, a circle, square, triangle and diamond by touch if the shapes are of a size to fit comfortably in a child's hand (Dickson et al. 1984).

Generally, the research literature focuses on children working with shapes in formal assessment contexts but not talking about shapes. The young children in Athey's study, in the naturalistic setting of a nursery class, do talk spontaneously about the shapes they create, but in this case the focus of the study is primarily on the representational features of children's constructions.

Perception of Spatial Patterns

A recent study of pattern perception has focused on an age group beyond the bounds of this study. Orton's (1999) study, focusing on children from 9 to 16 years, examines children's responses to spatial patterns as well as repeating number patterns. One of the findings of this

study, and one that is relevant to a consideration of the curriculum for younger children, is that children aged 9 to 10 often lack the vocabulary to effectively articulate their evident knowledge and understanding about pattern.

Rawson's (1993) study also examines pattern perception but in younger children. His sample is aged between 4 and 6 years, with the youngest child aged 4 years and 11 months. Task materials include items with linear repeating patterns and 2D spatial patterns. In searching for patterns, the children in this study demonstrate a range of different understandings of pattern. Children's responses are exemplified by their verbal responses to a piece of Christmas wrapping paper. Rawson observes how children struggle to express their perceptions. However, as a positive finding of this study, Rawson (1993, p.32) identifies a "strong inclination for young children to search for balance," with several children commenting on the presence or absence of symmetrical features in task materials.

INDIVIDUAL DIFFERENCES

There are findings of small gender differences in children's work with shape and space. Nickson (1999) outlines findings of small differences in a recent study by Anghileri and Baron, focused on children from 21 months to 7 years in free play and structured play activities. During free play activities with poleidoblocs, boys showed a preference for building tall structures and trains, while girls showed a preference for sorting activities and building structures like playgrounds and palaces. Girls also paid more attention to colour in their work with blocks.

The reported findings on gender differences amongst older children are complex but there are some commonalities in findings. Nickson (1999), summarising studies in this area, reports that boys are found to have better visualisation skills than girls.

THEORETICAL ACCOUNTS OF WORK WITH SHAPE AND SPACE

Many studies of young children working with space and shape are primarily empirical studies, aimed at defining developmental sequences and establishing developmental distinctions in relation to task difficulty. Most, however, are framed within a context of theory, with Piagetian theory dominating the field. Booth's (1981) study is strongly influenced by Piagetian theory, as is Athey's (1990) study. The more recently developed stage theory of the Van Hiele has also been an influence on research in this area.

The Piagetian Tradition

Piaget's research programme was wide-ranging but included a strong focus on children's developing ideas about space and shape. 'The Child's Conception of Space' (Piaget and Inhelder

1967) and 'A Child's Conception of Geometry' (Piaget, Inhelder and Szeminska 1960) present the main findings of research in this field and outline Piagetian theory.

Clements and Battista (1992) discuss two major themes in Piaget and Inhelder's theoretical work relating to the development of geometric thinking. The first theme is concerned with the child's representations of space, explicated within the context of Piagetian stage theory. The theory proposes radical change in the structure of thought at the onset of each new stage. They describe the second major theme as the "progressive organisation of geometric ideas", with the development of geometric ideas following a definite and logical order (1992 p.422).

The Child's Representations of Space

Piaget's theory makes an important distinction between the perception and representation of space, with perceptual abilities developing over the first two years and representational abilities beginning to develop from around 2 years of age. Perception is defined as the early knowledge that is gained through the infant's active manipulation of objects in the environment (Dickson et al. 1984).

Piaget's theory describes how, from around 2 years of age, the child's representational abilities begin to develop. Children develop an increasing ability to represent active spatial experience through mental imagery. In Piagetian theory, representation accounts for children's new abilities to draw and construct shapes and to recognise shapes by touch (Dickson et al 1984). Piaget argues that, by around seven years of age, the average child will have completed the process of reconstructing spatial experience, for example through drawings and models, and will be entering the stage of concrete operations.

The Progressive Organisation of Geometric Ideas

Piagetian theory proposes an order for the child's progressive perception and then representation of space (Dickson et al. 1984). Representation begins with the topological relations, relations that are independent of size and shape. These relations are nearness, separation, order, enclosure and continuity. For example, the theory proposes that the young child, in early drawings, does not distinguish circles from squares or triangles, since each is drawn as an irregular enclosed shape. Later on, the child moves on to represent projective relations. This involves the ability to predict how objects will look from different angles. Finally, from about 4, the child begins to represent Euclidean relations, such as those relating to size, distance and direction. Representation of Euclidean relations develops slowly over the period from about 4 years to 6 or 7-years of age.

Several aspects of this topological primacy theory have been questioned (Clements and Battista). For example, Piaget's use of several key terms, including topological, proximity and Euclidean, has been described as mathematically inaccurate. Additionally, the mutually exclusive classification of figures as topological and Euclidean has been questioned. Their

review of research studies focused on early shape discrimination led Clements and Battista (1992, p.425) to suggest that early shape discrimination may depend on “visually salient. properties (such as holes, curves and corners), simplicity and familiarity - rather than topological versus Euclidean properties...”

Clements’ and Battista’s review of drawing studies also leads to questioning of the topological primacy theory. They suggest that all three kinds of geometric ideas, topological, projective and Euclidean, may develop simultaneously and become increasingly integrated during early childhood. They argue that these geometric ideas are originally intuitive, grounded in the child’s actions, for example perception, drawing and construction. Their conclusion is that “research is needed to identify the specific, original intuitions and ideas that develop and the order in which they develop” (1992 p.426).

The Van Hiele Levels of Geometric Thinking

The Van Hiele theory relating to the development of geometric thinking has some similarities with Piagetian theory but differs in significant ways. Clements and Battista (1992) outline the key characteristics of this theory.

Five Levels of Development

The Van Hiele theory, in its first formulation, proposes five levels of development. In more recent work, three levels are described, with levels less finely delineated. The first three levels of the original five level theory are outlined in this section. Levels 1 and 2 are most relevant to the development of geometric thinking for children in the foundation stage.

- **Level 1: Visual**

Children characteristically “recognise figures as visual gestalts” (Clements and Battista, p.427). Children can name shapes and represent them as visual images. However, children’s recognition of the properties of shapes remains implicit.

- **Level 2: Descriptive/Analytic**

Children’s recognition of the properties of shapes becomes explicit, and they begin to develop an awareness of the parts of shapes. This new recognition of properties is developed in the context of practical activities, for example as children measure, draw and construct shapes.

- **Level 3: Abstract/Relational**

Children work with more abstract definitions of shape with guidance.

Characteristics of the Theory

The theories of Van Hiele and those of Piaget both emphasise the child's active role in the construction of knowledge and the importance of nonverbal, physical experience in the development of geometric thinking. Like Piagetian theory, the Van Hiele theory hypothesises discontinuities as well as continuities in children's development, with the appearance of qualitatively different levels of thinking at particular points in development.

In the Van Hiele theory, progress through levels is hypothesised as dependent upon instruction, rather than age or maturation. This emphasis on instruction contrasts with Piagetian theory, with its greater emphasis on biological maturation and self-directed experience. Additionally, the Van Hiele theory proposes that, at each level, some geometric ideas are understood only implicitly. Children move on to achieve an explicit understanding of these ideas at the next level. Finally, each level has its own characteristic language structure, with mathematical language an important factor in development.

Clements and Battista, reviewing the wide research literature focused on the Van Hiele levels, conclude that these levels do present a broadly accurate picture of the development of children's geometric thinking. However, they suggest the need to consider a Level 0 more basic than the proposed Level 1, a level they characterize as a 'pre-recognition' level (1992 p.429). The description of this level draws on Piagetian theory and Piaget's characterisation of the sensorimotor period.

SPATIAL PATTERNS: SUMMARY AND DISCUSSION

Children's Skills in Devising Spatial Patterns

A small number of studies have focused on the way young children combine lines, marks and shapes to create simple patterned configurations. A wide range of patterned configurations in children's early art work are identified by Kellogg (1964). Some but not all of these configurations are identified in later studies. Athey's study evidences children as young as 3 and 4 creating some simple patterned configurations, although mainly in work with paint and drawing media. Booth (1981), working with 5 and 6 year olds, presents details of a range of similar and more complex work, with children's painted spatial patterns based on translations, divisions of a plane and reflective symmetry.

Developmental Pathways to Spatial Pattern-Making?

A small number of studies propose developmental pathways in spatial organisation, sometimes leading towards 2D pattern-making. There are some parallels in the reported work undertaken with 3D materials. Studies (Kellogg 1969; Booth 1981; Fenson 1985) identify an initial scribbling period, an exploratory period of varying length. The starting age varies and may be related to the media and to experience. In play with blocks, there is an early manipulative

stage prior to children's first constructions. Children's use of materials comes under increasing visual and motor control during this period. Common findings relating to mark-making media are that, towards the end or following this period, children develop the ability to make one directional lines and dots or dabs. In children's drawings, this is usually achieved by 3 years. An ability to make an enclosed, circle-like shape develops at around the same time.

Linear organisation in work with blocks seems to parallel this development. Once children have achieved this level of control, study findings are that many go on to combine lines in simple ways, for example as crosses, and as rectangles. Simple enclosures are similarly reported in children's work with blocks. In work with mark-making media, lines and other elements are often repeated, for example in parallel lines and grids, the translation patterns identified as commonly occurring by Booth (1981). Some children then move on to an exploratory period of varying length, when the early shapes, circles and rectangles, are combined with lines and sometimes dabs or dots in increasingly complex geometric configurations. Similarly, the early spatial configurations observed in children's work with blocks are combined in more complex constructions.

Most researchers working from the perspective of art education go onto chart the child's progress towards representational drawing. Booth's study, working from the perspective of mathematics education, proposes a pathway towards more complex geometric pattern-making. Some of the important details of this pathway have been confirmed by other studies (Dickson et al. 1984), for example the developmental order for transformations.

Early Spatial Organisation

Some studies focus in a more detailed way on the earliest stages in children's developing control of media and spatial organisation. Copying adult modeled line drawing begins from 2 to 3 years but copying basic shapes extends in a developmental sequence from the first drawing of circles at about 3 to drawing diamonds at 7 years (Cox 1992). Spontaneous line drawing is commonly identified from 3 to 4 years, with rough circles also appearing during this period (Cox 1992). Evidence relating to ages for the spontaneous appearance of other shapes is more limited, however. Children often follow self-initiated rules in early drawing, rules that may support skill acquisition (Goodnow 1977).

Dimensions of Task Materials

Some studies suggest that drawing media are relatively difficult for young children to control. There are findings (Dickson et al. 1984) of children copying shapes at a younger age and more accurately with sticks than drawing. A proposed explanation is that drawing fails to allow for the trial and error placement of separate parts that is possible with some other materials. Paint may be more difficult to control than drawing media, with some of Booth's (1984) children going through an early scribbling stage in work with paint at 5 to 6 years.

Shape Recognition and Pattern Perception

A range of studies chart children's progress in shape recognition, with many children successfully recognising basic shapes by touch by 3½ years (Dickson et al.1984). Few findings relate to young children talking about shape, except in contexts where children use shapes for the purposes of representation (Athey 1990).

One study (Rawson 1993) of pattern perception in 4 to 6 year olds focuses more directly on children's attempts to articulate their perceptions. Children's talk, in several cases, provides evidence of a motivation to search for balance in visual materials and an implicit awareness of the importance of symmetry as a feature of pattern.

Theoretical Accounts of Work With Shape and Space

Several studies of young children's play with materials, focused on shape and space, have been framed within the context of Piagetian theory (Athey 1990; Goodson 1982; Booth 1984). Clements and Battista (1992) outline two major themes of Piagetian theory relating to children's thinking about shape and space. The first theme concerns the child's representations of space and this is set in the context of stage theory. Representational abilities, developing from about 2 to 7 years, account for children's progressive mastery of shape drawing and construction. The second theme of Piaget's work in this area focuses on the child's development of geometric ideas. Piaget's topological primacy theory identifies a sequence for the development of geometric ideas. In representation, children initially focus on topological properties; they move on to distinguish projective properties; and finally they distinguish Euclidean properties.

The Van Hiele theory, relating to the development of children's geometric thinking, is the second major theoretical account of development in this field, although it has not directly shaped the studies reviewed in this chapter. The Van Hiele theory, before later revisions, proposes five levels of development, levels that have been broadly supported by more recent research. The first and second levels are most relevant to studies of children in the foundation stage. At the first visual level children recognise figures as wholes and the recognition of properties remains implicit. At the second level, this early recognition of properties and parts becomes explicit.

DIRECTIONS FOR RESEARCH

National Numeracy Strategy goals and guidance (DFEE 1999) include an expectation for 4 and 5 year olds, by the end of the reception year, to devise spatial patterns with a variety of media. Both this document and the Curriculum Guidance for the Foundation Stage (DFEE 2000) include an expectation for children to recognise, talk about and recreate patterns, including spatial patterns.

The competencies of 3,4 and 5 year olds

The research base underpinning approaches to spatial pattern-making in the foundation stage curriculum is strongest in terms of children's use of drawing and paint media. Studies in this area provide some evidence relating to children's skills in spatial organisation at 3 to 6 years of age. However, only one study by Booth (1981) has an explicitly mathematical focus on spatial pattern-making. There are interesting studies focused on children's skills in spatial organisation in the use of other materials, for example blocks, but there is only a limited focus on spatial pattern-making in these studies. Beyond Booth's study of a slightly older age group, working with one medium, there is no detailed evidence relating to firstly, the numbers of 3, 4 and 5 year olds who can successfully devise spatial patterns or secondly, the nature of the patterns that they make. There is research evidence relating to children copying shapes but not copying spatial patterns. There are significant weaknesses in the research base relating to children's skills in spatial pattern-making and a need for further research in this area.

Developmental pathways

There are similar gaps in the research base relating to developmental pathways towards spatial pattern-making, with again studies primarily focused on development towards representational work using drawing media. In considering developmental pathways, it is also important to acknowledge the ways that individual differences in the quality and pace of development might militate against the idea of a single developmental pathway (Meadows 1993). Both the Kellogg (1969) and the Booth (1984) studies present logically plausible sequences but may underestimate the nature and extent of individual differences in development. A longitudinal study, focused on the development of individuals, would be a useful check against this approach.

Pattern perception

No studies to date focus on the skills of 3 year olds or younger 4 year olds in talking about spatial patterns. Young children's skills in talking about spatial patterns and the nature of pattern perception amongst 3 to 5 year olds is an area warranting further study. Additionally, to support teaching and learning in the foundation stage, it would be useful to extend knowledge about the impact of the different dimensions of play materials.

Individual differences

A recent study has identified small gender differences in young children's free play with wooden blocks but the study was not focused on spatial pattern-making. Further gender differences are reported in relation to the visualisation skills of older pupils. Generally findings in relation to gender and this aspect of mathematics are complex and little research has focused on children in the foundation stage. It would be useful to examine this area further.

The dimensions of task materials

Few studies reviewed, relating to shape or spatial patterns, have considered developmental distinctions in terms of the dimensions of task materials. However, two studies do report on children's relative success in copying shapes using sticks rather than mark-making media. It would be productive to focus on development in spatial pattern-making using mathematics apparatus or materials that may be easier to control than mark-making media, for example pegs and pegboards.

CONCLUSION

Significant gaps and areas of weakness have been identified in the research base underpinning the mathematical study of pattern for children in the foundation stage. There are weaknesses in both the literature relating to young children and repeating pattern and the literature relating to spatial patterns. The gaps and areas of weakness are most significant in relation to 3 and 4 year olds. There is a wider research base and some relatively secure research findings relating to 5 year olds. Identified gaps and areas of weakness have supported the delineation of some broad areas for further research.

These broad areas closely match the review areas identified at the beginning of the chapter, areas linked to the dimensions of difference in recent early years mathematics curricula identified in Chapter 1. Relating specifically to 3 and 4 year olds, these broad areas for further research are:

- children's competencies in linear repeated pattern-making and spatial pattern-making
- children's relative skills in copying, continuing and devising patterns
- the relationship between children's representational and pattern-making competencies in work with 2D and 3D materials
- pattern perception and children's abilities to talk about pattern
- developmental pathways to repeated and spatial pattern-making
- individual differences, including gender
- developmental distinctions in the dimensions of pattern-making materials

This is a wide area for potential research. However, the framing of more precise research questions to be taken forward into the main study is delayed until the next stage of the study. The existing research literature is too narrow and in some cases too flawed by methodological difficulties to effectively support this process. In the Sternberg (1974) and Pieraut-Le Bonniec (1982) studies, for example, the formal assessment contexts and the nature of assessment tasks for 3 year olds may have led to underestimation of the competencies of some children.

Aubrey's (1993) recognition of "understanding as situated cognition" leads to the conclusion that the assessment of young children should be "embedded in the context of known situations and authentic activities." An exploratory pilot study, focused on the pattern-making activity of 3 and 4 year olds in a nursery setting, was developed from this recognition. It is presented in Chapter 3. The findings of this first pilot study are then examined in the light of the existing research literature and together these are used to frame the precise questions to be taken forward into the main study.

CHAPTER 3

THE PILOT STUDIES

INTRODUCTION

Issues raised by reviews of the historical background to the study and the research literature have prepared the ground for two pilot studies with distinct aims and methodology, to be presented in this chapter.

Firstly, the review of the historical background to the study in Chapter 1 led to the identification of key dimensions of difference in approaches to pattern in recent early years mathematics curricula. These dimensions of difference provided a framework for an evaluation of the research base informing approaches to pattern in curriculum guidance for the new foundation stage.

Secondly, the review of research literature in Chapter 2 led to the identification of significant gaps and areas of weakness in the research base informing approaches to pattern in curriculum guidance, leading to the delineation of a broad area of focus for research. In Chapter 3, this broad area of focus is examined further in the light of evidence from the first pilot study.

The literature review also raised methodological issues, in particular issues relating to the assessment of young children. Drawing on recent perspectives from cognitive science, highlighting the ways that “knowledge and thinking are inextricably intertwined with the physical and social situations in which they occur” (Putnam, Lampert and Peterson 1990, p. 93), the importance of assessing young children in familiar contexts, using authentic activities, was acknowledged. This perspective was influential in shaping the first pilot study. The first pilot study itself presented further opportunities for the consideration of methodological issues.

The aims of the first pilot study were:

- to explore a broad research focus on the pattern-making activity of 3 and 4 year olds in a nursery setting
- to refine the broad research focus into a set of specific research questions
- to support planning of an appropriate research strategy and the methods and techniques to be employed in the main study

With the research questions defined and a research strategy in place, The second pilot study was intended to take the research forward, preparing the ground for the main study. The aim of the second pilot study was:

- to trial the specific assessment methods to be used in the main study

THE FIRST PILOT STUDY: DEFINING THE RESEARCH QUESTIONS

AIMS

As stated in the introduction, the first two aims of the first pilot study were:

- to explore a broad research focus on the pattern-making activity of 3 and 4 year olds in a nursery setting
- to refine the broad research focus into a set of specific research questions

In this, the first section of Chapter 3, the exploratory process, the research findings and the finalised research questions are outlined.

METHODOLOGY

The Sample

The sample for the first pilot study was made up of 3 and 4 year olds from an inner-city nursery class, where 52 children attended for morning sessions and 52 children attended for afternoon sessions.

Data Collection

The data collection was structured in relation to the broad areas for potential research identified at the end of Chapter 2, with two omissions noted below. Relating specifically to 3 and 4 year olds, the resultant broad areas for research were:

- children's competencies in linear repeated pattern-making and spatial pattern-making
- children's skills in copying, continuing and devising patterns
- the relationship between children's representational and pattern-making competencies in work with play materials
- pattern perception and children's abilities to talk about pattern
- developmental pathways to repeated and spatial pattern-making
- individual differences, including gender
- developmental distinctions in the dimensions of pattern-making materials

Recognising constraints on the breadth of the main study, an explicit focus on children's use of 3D materials was omitted from both the pilot and the main studies. Additionally, without a quantitative strand to the first pilot study, a potential main study focus on quantifying children's relative skills in pattern copying, continuing and devising activities was omitted from the first pilot study.

Research data was collected by the teacher-researcher over a four month period. It consisted of dated diary observations of 3 and 4 year olds engaged in a wide variety of activities considered to have potential for pattern-making. It also included photographs and examples of

children's work. Diary observations were made and work collected when children chose to engage in activities with the potential for pattern-making. Children's use of language was recorded in diary entries where possible. In some cases children were invited to talk about their work or encouraged to respond to adult comments. No protocol was followed and an attempt was made to replicate every-day classroom interactions, using familiar classroom materials. Contextual details, including details of the adult role in the activity, were also recorded.

Over the four month period, 60 children were observed and 101 observations made. Thirty-seven children were observed on one occasion only. Twenty-three children were observed on two or more occasions.

Play Materials

Children were observed in varied classroom contexts, using a variety of play materials. The potential of play materials for different kinds of early patterning play and pattern-making varied. Firstly, during adult focus activities, children were observed playing with materials with the potential for linear, patterned sequences only, for example beads. Secondly, they were observed playing with materials with the potential for both linear, patterned sequences and 2D spatial patterns, for example pegs and pegboards

The range of play materials used during the first pilot study was wide. It included mathematical apparatus, for example, a collection of large and small threading cubes, as well as pegs and pegboards; it included creative materials, for example collage and printing materials, paints and felt pens; and it included a construction set, duplo.

Play Contexts

Children were observed in three contrasting contexts. Firstly, they were observed as they engaged in self-initiated play without adult support, using materials selected from classroom provision. Secondly, children were observed as they worked with materials selected by the teacher-researcher. In this context children were invited to make a pattern with play materials but no adult model of pattern-making was provided. In the third context, children were again observed as they worked with materials selected by the teacher-researcher. However, in this context they were invited to make their own patterns, following observation of an adult engaged in pattern-making. In most cases the model was a simple alternating pattern.

FINDINGS

Unstructured play

A small group of children interacted with play materials primarily at a physical level and did not structure either their selections or arrangements of materials. Firstly, several children seemed preoccupied with consolidating physical skills, for example threading skills. Secondly, a

small group seemed primarily focused on the setting as a context for social interaction. It seems likely that the relative frequency of unstructured play was underestimated by the sampling methods of the diary study. Children were not selected for observations randomly. In many cases children were observed because they were doing something 'interesting'. In fact 'interesting' usually meant that the child was structuring their selection or organisation of materials in some way.

Imaginative play

Another small group of children structured play materials but not in terms of spatial organisation. These children structured play materials to represent personal or imaginative experience. In some cases it was the structure of the finished product that suggested the imaginative content to the child. For example, Sean, at 4 years 5 months, glued varied collage pieces to a strip of card without evidence of planned spatial organisation, and commented, "It's a jungle".

The pilot study data suggests that for many children at this age, the motivation to use play materials imaginatively is predominant. Rebecca, at 4 year 5 months, began threading beads from a set of large and small beads of different colours. She selected all large beads but did not select beads by colour. After a short period she seemed to become bored and announced, "I can build". At this point she stopped threading and began to arrange a long row of beads on the table, followed by a shorter row of beads on top. When nearly finished she said, "I'm making a choo-choo."

In the first pilot study, some children did not make a clear distinction between the imaginative and mathematical purposes of their play. A small group of children engaged in storying with play materials but at the same time structured aspects of their work through sorting and spatial organisation. Leanne, at 4 years 7 months, selected matchsticks and material squares from a variety of collage materials. She arranged these with some alternating of elements. Asked about her work, Leanne described it as a 'pattern-slide' and then went on to describe in detail each element in the arrangement as a part of a children's playground.

Attribute based Sequencing

A majority of the children observed during the first pilot study evidenced pattern-making skills or organised materials in ways that may be related to pattern-making. A high frequency of recorded work incorporated attribute based sequencing. However, methodological problems, to be discussed below, led to difficulties in assessing intentionality in the work of some children, particularly in work with collage and printing materials. Many children attended to the attributes of colour, shape and size when selecting and sequencing materials. Additionally, several children attended to orientation in linear sequences. Several kinds of attribute based sequencing were observed.

Many children structured play materials by sorting similar objects. Mark, at 3 years 11 months, selected only paper triangles for his collage work. He sorted from a collection of squares and triangles, saying, "I've done loads of triangles." Laura, at 4 years 2 months, selected large beads from a collection of large and small beads but seemed to pay no attention to the colours of beads.

Many children, having chosen colour, shape or size as an attribute for sorting, began sorting with one criterion and then changed the criteria. Using the attribute of size, David, at 3 years 9 months, began by threading large beads and then changed to threading small beads, saying, "I can find some more little ones". Daniel, at 3 years, 10 months, alternated sequences of large and small beads, threading 5 large beads, 6 small beads, 4 large beads and then 6 small beads. Children who were attending to colour as an attribute did similar work. Sapphire, at 4 years 2 months, working with beads, made a sequence of colour sortings but with irregular numbers of beads in each set. Just one child, Laura, at 4 years 8 months, made a sequence of colour sortings with a regular set size, in this case two.

In the data relating to work with beads, some children worked with two rules simultaneously. For example, Daniel at 3 years 9 months, threaded 9 small, red beads, selecting beads according to the attributes of colour and size.

Repeated pattern-making

A key finding of the first pilot study was the low frequency for observations of children making repeated patterns. Only 14 of the 59 children observed were successful in copying, continuing or devising repeated patterns.

Repeated pattern-making varied, with children using one or more of the attributes of colour, shape, size and orientation in their work. Patterns were also made with several different play materials. For example, at 4 years 8 months, Sian made a repeated yellow and blue pattern across one line of a pegboard. Haley, at 3 years 5 months, repeated a sequence of 2 small and 1 large bead six times in work with beads. In addition, three children successfully continued a repeating yellow and blue pattern made with duplo bricks and started by an adult.

A small number of children made more complex patterns, incorporating linear repeating sequences. One child, Sally, at 4 years 8 months, used colour in a spatial pattern based on rotation about a point. A sequence, made up of a red radial followed by 3 regularly arranged dabs (green, yellow, green), was repeated around the circle. Working with collage shapes, Rosa, at 3 years 8 months, repeated a sequence of two triangles and two squares. Few children were observed across contexts in the pilot study but one child, Gina, at both 4 years 2 months and 4 years 5 months, made repeating patterns with 3 kinds of collage materials, using the attributes of colour, shape and orientation in her work.

Spatial Structuring

Analysis of the data from the diary study shows a small group of children placing play materials in an apparently random manner and a larger group of children structuring materials spatially, but in a wide range of ways. All the play materials used in the study, except for beads, allowed for the possibility of spatial structuring. When children thread beads, however, a linear arrangement is made by default.

Linear organisation

In the first pilot study, a majority of the children observed made simple linear arrangements of materials. This linear organisation of materials was supported by the strips of card provided for some collage and printing work, as well as by adult modelling of linear arrangements. However, during these activities, some children did place materials on top of each other or in an irregular manner. Other children, evidencing an intention to arrange materials in a linear manner, experienced difficulties in sustaining linear organisation.

In work with pegs, duplo, collage materials and printing, nearly all children made linear arrangements of materials as modelled. The fourteen children who successfully continued or devised repeated patterns placed materials in a linear arrangement. However, in most cases the placement order of materials was not recorded and so there is no clear evidence that children's placed materials through uni-directional proximity placement.

There were relatively few observations of children organising materials in different or more complex ways in linear work. Two children, attempting symmetrical effects with the organisation of collage materials, moved from side to side of a line in their placement of materials.

2D organisation

Some children extended their initial linear organisation of materials. Three children working with collage materials added a second line of materials parallel to the first. Of the three children observed working with pegs and pegboard, one child extended the modelled single line of pegs, going on to place pegs around all four sides of the square pegboard.

Similar 2D developments of simple linear organisation were observed in the work of a small number of the children who coloured squares on a 6×6 grid, using 3 colours. Children were given no verbal prompt to engage in pattern-making and no models were provided. Many children became bored after colouring a few squares and left the activity, while many worked in a seemingly random manner. Some children however, worked systematically, colouring parallel rows of squares until their grid was completed. Melanie, at 3 years 9 months, talked about "rows of yellow" and coloured rows in the sequence, green, yellow, red, green, red, yellow. The work of these children shows an integration of attribute-based sequencing and 2D spatial organisation.

2D spatial patterns

Relatively few contexts were provided to support 2D pattern-making during the first pilot study and only a few children evidenced skills in this area. With a collection of wheels as a stimulus, some children evidenced a developing awareness of pattern in their paintings. This work was supported by discussion with an adult about the patterning of lines and circles on wheels. Several children, working on paper circles, painted concentric circles. Sally, as described above, and a small group of children combined concentric circles and regularly placed radials, creating simple rotation patterns.

Orientation

In work with collage and printing materials, many children controlled the orientation of materials, using orientation as an attribute in rule-based sequences. Most children placed collage squares and many children placed collage triangles in a regular manner. In collage work with card bottle shapes and matchsticks, several children structured materials spatially, incorporating control of the orientation of materials within a linear sequence. George, at 4 years 3 months, carefully placed vertical matchsticks in a row. On top of this configuration, he arranged two horizontally placed matchsticks end to end.

Just one child, Gina, at 4 years 2 months, used orientation as an element in a repeated pattern in collage work. Gina alternated vertically placed gold bottle shapes and vertically placed matchsticks, placing these in a line. Beneath this, she made a second repeating pattern, a sequence of vertically placed gold bottles with a horizontally placed matchstick on top of each bottle.

Integrated Attribute based Structuring and Spatial Organisation

Integrated attribute based structuring and linear organisation

In the first pilot study, the work of many children evidences an integration of attribute-based sequencing or repeated pattern-making and linear organisation. Many children making attribute based sequences or repeated patterns, seemed to work by placing materials next to each other, moving in one direction along a line. However, the placement order of materials was not systematically recorded.

Integrated attribute based structuring or repeated pattern-making and 2D organisation

The work of a smaller group of children shows an integration of attribute based sequencing or repeated pattern-making and 2D spatial organisation. Just one child successfully integrated repeated pattern-making and 2D spatial patterning. Sally, at 4 years 8 months, as described above, sustained a repeating pattern, incorporating dabs in 3 colours within a rotation pattern of concentric circles and radials. Two other children attempted to integrate repeating colours within a rotation pattern, although the repetition of elements was not sustained.

Developmental Change

Motivation

A key finding of the first pilot study was the seeming difference between 3 and 4 year olds in their motivation to engage in nursery activities with the potential for patterning play and pattern-making. The research methodology of the study led to poor sampling of 3 year olds relative to 4 year olds. There were approximately equal numbers of 3 and 4 year olds attending the nursery at the time of the research, with most children admitted to nursery shortly after their third birthday, but of the 60 children observed only 19 were 3 year olds. There was no intention to bias sampling in this way. It seems likely that 3 year olds were less willing than 4 year olds to accept adult invitations to join specific activities with the potential for patterning play and pattern-making.

Competencies

There was additional evidence suggestive of a difference between 3 and 4 year olds in terms of patterning play and repeated pattern-making competencies. Just 2 of the 14 children who were observed successfully continuing or devising repeating patterns were 3 year olds. Three year olds also seemed to experience greater difficulty controlling some of the materials used during pattern-making activities, in particular paint and printing materials.

Many of the 3 year olds observed were engaged in attribute based sequencing and spatial structuring. However, it is unlikely that these 3 year olds represented the range of abilities of children attending this nursery. Children with high level abilities were probably over-represented in the sample, as a result of the research methodology. In a naturalistic setting, with children choosing activities for the greater part of each session, it seems likely that younger children with relatively low levels of competence would be less attracted to the focus pattern-making activities.

Despite the considerable sampling problems discussed above, data from the first pilot study suggests the broad outlines of a developmental pathway or pathways towards repeated pattern-making for children from 3 to 4 years of age. An hypothesised developmental sequence progresses from non-patterning play, through simple to more complex forms of attribute-based sequencing, and then on to different kinds of pattern-making.

In the first pilot study, the limited range of observations of spatial pattern-making leads to difficulties in carrying out a similar analysis for spatial work.

Individual Differences

Individual differences in pattern related competencies, including gender differences, was an issue raised in Chapters 1 and 2. The issue of gender was raised through the examination of changing emphases in recent early years curricula in Chapter 1 and through the literature review

in Chapter 2. In the first pilot study, gender differences was identified as a significant issue, as were individual differences in language skills and number abilities.

Language

The first pilot study provides some evidence suggestive of a relationship between language skills and children's developing pattern-making skills. However, findings relate solely to children talking about their own patterns and there was no focused assessment of language skills.

Some children observed during pilot study activities were engrossed in their play, seeming reluctant to talk. Several children, invited to talk about their work, experienced difficulty in naming the key attributes of materials used, particularly the attributes of colour and shape. Several children were keen to talk but talk was often focused on social experience and not on the organisation of materials.

However, many children did talk in more focused ways about their work. Firstly, many children were successful in identifying the attributes of selected materials. Kay, at 3 years 6 months, for example, commented, "that's a circle and that's a circle and that's a circle ... " Additionally, several children generalised about their work using everyday language. For example, Marc at 3 years 1 month commented, "I've done loads of triangles."

A small number of the children observed used language to support planning. Dean, at 3 years 9 months, found a small bead and said, "I can find some more little ones." David, at 4 years 7 months used language to articulate a rule, "I'm always getting big ones." On one occasion, he verbally planned a repeated pattern, saying "Mines going green, yellow, green, yellow, green, yellow." In fact, he went on to alternate small sets of yellow and green beads but did not follow his plan exactly.

Not all children who engaged in early attribute based patterning play or pattern-making used language in the focused ways detailed above. However, the diary data does raise questions about the relationship between the attribute based structuring of materials and children's developing language skills. Knowledge of key attribute names and verbal planning skills, for example, may be particularly important in the development of repeated pattern-making competencies.

The first pilot study provides no similar evidence relating to children's talk about spatial patterning. This may be related to children's greater difficulties in this area but it may be a result of weaknesses in research methodology.

Number

The first pilot study evidences a wide range of levels in children's developing concepts of number and counting skills. Some evidence is suggestive of a relationship between development in this area and the development of repeated pattern-making competencies.

Several children counted materials spontaneously while playing and several children counted materials when invited to talk about their work. Jack, at 4 years 3 months, was at the lower end of the observed range. He counted the matchsticks on his collage without prompting, reciting the numbers, “1, 2, 3, 4, 7.” As he counted, Jack pointed to matchsticks but without matching numbers recited to matchsticks touched. At the higher end of the observed range, Dan, at 4 years 7 months, accurately counted fourteen large beads and then went on to draw this number of beads independently.

Fourteen children were successful in continuing or devising repeating patterns. Diary observations provide evidence relating to the concepts of number and/or counting skills of just four of these children. However, in all four cases children showed abilities at the higher end of the range.

Gender

During the first pilot study, children varied widely in terms of their motivation to participate and their ability to sustain concentration during focus activities. They also varied in the ways they worked with or structured play materials. The influence of age on motivation has been discussed. There was also some evidence suggestive of gender as a factor relating to these dimensions of variability.

The research methodology of the first pilot study led to poor sampling of boys, paralleling the poor sampling of 3 year olds. Although there were more boys than girls in the nursery, only twenty-four of sixty children observed were boys. There was no intention to bias sampling in this way. It seems likely that boys were less motivated than girls to accept adult invitations to join the focus activities. Of the fourteen children who were successful in continuing or devising a repeating pattern, only four were boys. Of the five children who were successful in integrating attribute based patterning play or repeated pattern-making and 2D spatial organisation, only one was a boy.

Dimensions of Play Materials

In the first pilot study children were observed in 12 contexts, making use of 8 different kinds of play materials.

Saliency of attributes

Findings are suggestive of a relationship between the saliency of attributes of play materials and both early attribute-based sequencing and pattern-making competencies. For example, during work with beads, where children could select beads by size or colour, size seemed to be the more salient attribute. Following modelling of a two colour alternating pattern, thirteen children worked with beads. The adult selected large beads for pattern-making but talked only about the colours used. All thirteen children structured sequences in terms of size, with only

two children attending to both colour and size in attribute based sequencing. A further two children showed some awareness of colour as an attribute, making reference to their use of 'all different colours.' In this context, nine children provided no evidence of attending to colour as an attribute.

Control of materials

In the first pilot study, there was some evidence that the control of materials might be a contextual variable, relating to early patterning play and pattern-making competencies. All children seemed to work confidently with beads, pegs and duplo bricks. However, some children, particularly younger children, experienced difficulties and frustration in handling other materials, for example paint, collage and printing materials. It seems likely that where children need to give high levels of attention to the control of play materials, there will be less attention given to the structuring of materials, either spatially or in terms of attributes.

SUMMARY AND IMPLICATIONS FOR THE MAIN STUDY

Styles of play

The first pilot study evidences some 3 and 4 year olds engaged in apparently unstructured play while working with materials with the potential for pattern-making. The frequency of such play may have been underestimated by diary study methodology. The data also evidences children structuring play materials to represent personal or imaginative experience while working in pattern-making contexts This suggests a need for the main study to raise questions about the frequency of such play in pattern-making contexts and to review the place of this play developmentally.

Attribute based Structuring

In the first pilot study, many children attended to the attributes of colour, shape, size and/or orientation when selecting and sequencing materials. Attribute based sequencing was a commonly observed response to adult modelling of repeated pattern-making. A smaller number of children made repeated patterns. Analysis suggests a need for the main study to raise questions about the frequency of different kinds of attribute based sequencing and repeated pattern-making in the play of the 3 to 4 year olds. There is also a need to examine the nature of attribute-based sequencing and its relationship with repeated pattern-making developmentally.

Spatial Structuring

In the first pilot study, a small number of children placed play materials in an apparently random manner. However, many children structured materials spatially. The most common organisation of materials was linear, with children commonly placing materials in lines. A small

group of children used simple 2D spatial organisation, for example placing pegs around the sides of a pegboard. The work of another small group of children evidences an awareness of symmetry. Analysis suggests a need to investigate more systematically firstly, the ways that 3 to 4 year olds organise play materials spatially; secondly, the frequency of this organisation; and thirdly, the development of both linear and 2D spatial organisation.

Integrated Attribute Based Structuring and Spatial Organisation

In the first pilot study, the work of many children evidences an integration of attribute-based sequencing or repeated pattern-making and linear organisation. The work of a small group of children shows an integration of attribute-based sequencing and 2D spatial organisation. Findings show the successful integration of repeated pattern-making and 2D spatial patterning in the work of just one child. There is a need to examine further the integration of attribute-based sequencing and spatial organisation in the work of 3 to 4 years, both the frequency and the development of such work.

Individual Differences

The first pilot study findings are suggestive of a difference between girls and boys, firstly in terms of their motivation to engage in patterning play and pattern-making and secondly in terms of their competencies in this area. Findings are also suggestive of a relationship between individual differences in the development of number concepts and counting skills and the development of pattern-making competencies. Further findings are suggestive of a relationship between individual differences in productive language skills and pattern-making competencies. These relationships, relating to individual differences, merit more systematic investigation in the main study.

Pattern Perception

Although there was no explicit focus on pattern perception in the first pilot study, many children did talk about aspects of their attribute based sequencing and linear repeated pattern-making. The first pilot study provides no similar evidence of children talking about 2D spatial patterning. This suggests that pattern perception in terms of 2D spatial patterns may be less developed than pattern perception in relation to linear repeated patterns. Alternatively, it may be more difficult for young children to articulate their pattern perception in relation to 2D work. This area merits more focused investigation.

Dimensions of Play Materials

In first pilot study findings, there is some evidence that the saliency of attributes of play materials might relate to early attribute-based sequencing and linear repeated pattern-making competence. Additionally, there is some evidence that the control of materials might be a

contextual variable, relating to early patterning play and pattern-making competencies. Issues relating to the dimensions of play materials are considered further in the discussion on methodology.

CONCLUSION

In Chapter 2, significant gaps and areas of weakness were identified in the research bases underpinning approaches to pattern in the foundation stage curriculum. Evaluation of this research base led to the delineation of a broad area of potential focus for research.

The first pilot study was successful in achieving its first aim, to explore a broad research focus on children's pattern-making activity in a nursery setting. With some qualifications in terms of 3 year olds and boys, the study was successful in sampling the work of 3 and 4 year olds engaged in a wide range of early patterning play and pattern-making activity. Observational data provided opportunities to analyse the work of children using a variety of play materials and with varying levels of adult support or scaffolding. Analysis of a rich set of data, set in the context of the earlier review of research literature, contributed to achievement of the first pilot study's second aim, that of refining the broad research focus into a set of specific research questions. Formulated in the context of the above discussion, the research questions to be taken forward into the main study are:

1. What knowledge, understanding and skills in pattern-making do children demonstrate at 3½ and 4½ years of age?
2. Where do knowledge, understanding and skills in pattern-making begin and how do they develop between the ages of 3½ and 4½ years?
3. Are there individual differences in the detailed pathways taken towards knowledge, understanding and skills in pattern-making?
4. Are there individual differences in knowledge, understanding and skills in pattern-making and in rates of development between 3½ and 4½ years?
5. Do individual differences in the development of knowledge, understanding and skills relate systematically to differences across other dimensions of development?

Two areas of sampling weakness in the first pilot study, the relatively poor sampling of 3 year olds and the relatively poor sampling of boys, arose from methodological problems that may be intrinsic to the diary study approach. This sampling weakness was one of a range of methodological issues raised by the first pilot study. In the following section, the first pilot study is re-examined in relation to the third of the three initial aims.

THE FIRST PILOT STUDY: METHODOLOGICAL ISSUES

The first two aims of the first pilot study have been addressed. The third aim was:

- to support planning of an appropriate research strategy and the methods and techniques to be employed in the main study

The analysis of data from the first pilot study raised important methodological issues. Some methodological problems have been noted in the previous section. However a wider review of methodological issues raised by the first pilot study is necessary to support planning of a research strategy for the main study.

The following aspects of methodology have been highlighted as key areas for review:

- the research strategy
- the nature and range of assessment materials
- adult scaffolding of assessment activities

In this second part of Chapter 3, each of these aspects of methodology is reviewed in turn.

Where the issues raised are interrelated, this is highlighted in discussion. Following this review, the methodological issues raised are summarised and the implications for planning the main study outlined. This leads into the presentation of the second pilot study in the final section of the chapter.

THE RESEARCH STRATEGY

To support further planning of the main study, the first aspect of first pilot study methodology to be reviewed is the research strategy. The first pilot study used a diary study approach, with children observed during play in the naturalistic setting of a nursery class. The rationale for the first pilot study research strategy is discussed below.

Firstly, the diary study is considered to be an appropriate research strategy to support a broad exploration of a wide field. A diary study has elements in common with a case study. Robson (1993) outlines the case study and describes it as traditionally associated with exploratory research. Secondly, the diary study is considered to be a valuable research strategy in that it takes advantage of the strengths and accommodates to the difficulties of the teacher-researcher role. Burgess (1984), describing the role of diary records in social investigations in school settings, presents a case for diary study as a particularly useful strategy for the teacher-researcher. Thirdly, the diary study of an individual child is a research methodology with a long tradition in developmental literature. Coolican (1990) traces observational methods back to the late 19th century, citing Charles Darwin as the most famous compiler of developmental records from this period. Piaget continued the tradition into the 20th century with the important diary records of his own three children's development through infancy. It is necessary to note,

however, that the first pilot study replicated only the observational features of these studies and not the longitudinal aspect. Fourthly, and related to the previous point, the diary study methodology is based on the assessment of children through close observation, in a naturalistic and therefore ecologically valid context. The particular value of this approach to assessment is considered in the following section.

Evaluation of the diary study strategy, as used in the first pilot study, shows it to have considerable strengths, particularly in relation to the exploratory aims of this phase of the research. However, in planning a research strategy for the main study, it is necessary to consider both the strengths and weaknesses of the first pilot study methodology.

Ecological Validity

The ecological validity of assessment contexts is a major strength of the diary study approach. The assessment contexts used during the first pilot study were representative contexts from the naturalistic setting. Bruner and Haste (1987 p.2), reviewing issues in developmental psychology over the previous decade, cite “ the nature of the settings in which we observe (or ‘experiment’ with) the signs of growth in the developing child” as a key methodological issue for developmental psychology. Ecological validity is an important issue for researchers working with young children.

In England, a tradition of child development research, rooted in naturalistic settings and with close links to early years pedagogy, began with the work of Susan Isaacs at the Malting House school in the 1920s. Isaacs (1936) argues that young children are most appropriately assessed in play contexts, with children and adults participating in shared practical activities. In a review of research approaches to work with young children, Athey (1990, p17) argues that observational research, of the kind undertaken by Isaacs as a teacher-researcher, can offer “positive descriptions of cognitive competencies in young children”. Athey contrasts Isaacs’ descriptions of competencies with deficit descriptions, often arising from formal testing and exemplified in Piaget’s findings for 2 to 5 year olds.

During the first pilot study children were observed working in a familiar environment with a familiar adult. They were mainly confident, well motivated and keen to communicate with peers and/or adults. It seems likely that the naturalistic context supported the demonstration of children’s competencies. Confirming the strength of this approach, the diary study resulted in a rich set of data, including varied examples of non-patterning play, as well as several kinds of early patterning play and pattern-making. These positive findings lend support to the use of a diary study as one strand within the main study research strategy.

Sampling

While the ecological validity proved to be strength of the first pilot study, other features of the research strategy were problematic. Sampling proved to be a particular weakness. Two

kinds of sampling problems were experienced. There were problems involved in sampling the 'reluctant patterners,' those children who were not attracted to focus assessment activities. There were also problems involved in sampling self-initiated, early patterning play and pattern-making using self-selected materials.

Reluctant patterners

Children's positive attitudes to assessment activities during the first pilot study may have been related to the fact that children choose to participate in activities. However, this positive feature of the research was related to a negative feature, noted earlier. In the first pilot study, the sampling of 3 year olds and boys was relatively poor. It seems likely that a group of children, including a relatively high proportion of 3 year olds and boys, were not attracted to focus activities and choose not to participate. This group may have included a relatively high proportion of children with low levels of competence, resulting in a sample that was far from representative of the nursery class.

Coolican (1990) discusses similar problems of sampling bias in relation to the use of the volunteer subjects who are frequently used in experimental studies. Sampling bias was not a serious problem for the first pilot study, in so far as this was an exploratory phase of the research. However the problem of sampling bias, with the consequent limits on generalising research findings, militates against the use of a diary study approach as the sole or primary research strategy for the main study.

Self-initiated Patterning

An aim of the first pilot study was to observe children working in two contrasting but representative settings; firstly, in self-initiated work with self-selected materials and without adult support; and secondly with materials set up by an adult and/or supported by an adult focus. A rich set of data, including varied examples of patterning play and pattern-making, was collected in the settings with adult involvement. However, little data was collected showing evidence of self-initiated patterning play or pattern-making.

In a discussion of self-initiated learning in early childhood, Deloache and Brown (1987 p.111) note the prevalence and significance of this kind of learning. They present research evidence to support the view that "Children are not only problem solvers, but also problem creators: they not only attempt to solve problems presented to them, but they also seek novel challenges." In selecting a diary study approach, it was considered important to sample children's self-directed learning as "problem creators" in work with materials with the potential for pattern-making.

One explanation for the low levels of observations of self-initiated work in the first pilot study is that the nursery children rarely engaged in self-initiated patterning play or pattern-making. A second explanation is that nursery children engaged mainly in patterning play but that

this was excluded from the implicit definition of 'interesting' activities. A third explanation, arising from the problematic teacher-researcher role, with conflicting pressures on time and attention, is that observation of self-initiated work was given too low a priority in the research schedule. A final and related explanation is that the research focus on self-initiated learning was too wide, with a target group of approximately 100 children.

Analysis of the first pilot study leads to the conclusion that any observational strand relating to children's self-initiated work within the main study research strategy would require a narrower focus on a relatively small group of children. It would also need to include an explicit focus on patterning play, both play incorporating attribute based sequencing and play focused on the spatial organisation of materials.

Protocols

A strong feature of the first pilot study was the positive attitudes demonstrated by children during assessment activities. However, this strength was related to the weakness in relation to sampling discussed above. It was related to a further weakness, the low reliability of study findings.

Loose structuring and lack of a protocol for assessment activities detracted from the reliability of findings during the first pilot study. The first pilot study attempted to provide groups of children with the same assessment materials in a broadly similar context. The study also attempted to replicate the supportive adult-child interactions of the naturalistic setting. The two aims are to a degree contradictory and children were in fact given levels of verbal and visual support that differed in small but significant ways. Coolican (1990) emphasises the inverse relationship that exists between reliability and ecological validity. Aspects of the first pilot study confirm this.

Given the exploratory focus of the first pilot study, the low reliability of findings, arising from a lack of standardised procedures, is not a serious weakness. However, reliability is an important issue to be considered in planning a research strategy for the main study.

Developmental Issues

The first pilot study findings raised developmental issues, outlined in the first part of this chapter. The first issue raised was that of developmental change in children's motivation to engage in pattern-making activities. The second issue raised concerns the possibility of a developmental sequence from early patterning play to linear repeated pattern-making. The diary study methodology, however, although successful in raising developmental issues, was not an appropriate strategy for investigating such issues.

The diary study, as used by Piaget in his accounts of his own children's early development, has traditionally focused on the development of young children over time. However, a longitudinal dimension was missing from the diary study approach of the first pilot

study. Observations were collected over a four month period, a relatively short period of time developmentally, and in the main the diary comprised individual snapshots of children at particular stages of development. Although some children were observed on two or more occasions, contextual variables, as well as the short time-scale, prevented a clear focus on the development of individuals over time.

Researchers often use cross-sectional studies, as well as longitudinal studies to examine change over time. However, the 3 and 4 year olds included in the first pilot study did not form two distinct groups. The ages of the children were on a continuum, with a relatively high proportion of 4 year olds. Therefore, comparison of the patterning play and pattern-making of the 3 and 4 year olds as two distinct groups is problematic. In conclusion, to investigate developmental issues effectively, the main study would need a new research strategy, perhaps one including both longitudinal and cross-sectional strands.

Individual Differences

The first pilot study raised questions about the relationship between differences in pattern-making competencies and aspects of developing cognition, in particular number concepts and skills, and language skills. Additionally, the first pilot study raised questions about the relationship between gender and children's pattern-making competencies.

Number and language development

During the first pilot study observational data were collected relating to firstly, children's number concepts and skills, and secondly, children's productive language skills. Data were collected, where possible, in the context of children's patterning play and pattern-making. However, data were not collected for all children and the quality of data varied. This was in part a consequence of the fact that many children worked without talking and did not show evidence of developing number concepts or skills during focus activities.

The relationship between children's pattern-making competencies and aspects of developing cognition merits more systematic investigation. There is a need for the main study to include specific assessments of those aspects of cognition that may be associated with patterning play and pattern-making competencies.

Gender

During the first pilot study, there was evidence suggestive of firstly, gender differences in children's motivation to engage in pattern-making activities and secondly, gender differences in pattern-making competencies. To investigate gender differences effectively, the main study would need a new research strategy, ensuring systematic sampling of the two groups and comparability of assessment tasks.

Triangulation

The diary study methodology, as used in the first pilot study, is an effective strategy for use during the early and exploratory phase of a study. However, the discussion above confirms that this methodology alone cannot support the more systematic and focused investigation of specific research questions necessary in the main study.

While recognising the limitations of the diary study methodology, however, it is important to note that this approach incorporates elements that it would be important to retain within a main study research strategy. In particular, the diary study allows for the observational study of young children in a naturalistic setting, facilitating positive descriptions of children's competencies. It answers some of the methodological problems specific to work with young children.

Contrasting perspectives on the diary study approach suggest a need to give careful consideration to the issue of triangulation in planning the main study research strategy. Triangulation, involving the use of two or more research methodologies, has important advantages for any study, allowing for the possibility of dual or multiple perspectives on a research problem. It is likely to yield both qualitative and quantitative data. Triangulation is particularly important where complex, human behaviour is studied. Cohen and Manion (1989) discuss the importance of using multiple methods to minimise the potentially distorting effects of a single methodology.

Robson (1993, p.290) reviews additional advantages, as well as criticisms of a multiple methods approach. Some of these advantages are relevant to the present research. Firstly, the use of multiple methods should result in a "reduction of inappropriate certainty". Secondly, different methods can be used to focus on "different but complementary questions within a study." Thirdly, the use of multiple methods can be used to "enhance interpretability" at the stage when results are being analysed. In conclusion, the main study would need to consider the advantages of multiple methods.

THE NATURE AND RANGE OF ASSESSMENT MATERIALS

The research strategy of the first pilot study has been reviewed to support the planning of a research strategy for the main study. To support more detailed planning of the main study methodology, a further aspect to be reviewed is the nature and range of the assessment materials used in the first pilot study.

Children during the first pilot study used a wide range of play materials. This range was important to the exploratory phase of the research. First pilot study findings are that the nature and range of materials used by children has a significant effect on the quality and range of the data gathered. A set of key criteria, relating to the effects of play materials, are presented below.

Play materials vary in terms of:

- potential for allowing children to demonstrate a range of early patterning and pattern-making competencies
- suitability for eliciting patterning as opposed to symbolic play
- attractiveness to young children
- associated management demands
- associated ambiguity and/or complexity in terms of the data yielded
- manageability in relation to the recording of both process and product.

In the following section, an analysis of the play materials used during the first pilot study, using these criteria, supports the selection of play materials for the main study.

The Pattern-making Potential of Play Materials

Ten different kinds of play materials were used during the first pilot study. However, the range of these materials placed limits on the range of pattern-making activity observed. Selected play materials provided varied opportunities for children to engage in attribute based sequencing and repeated pattern-making. They also provided varied opportunities for linear sequencing. However, few contexts were successful in providing opportunities for children to extend their linear organisation of materials in 2D spatial arrangements or to engage in 2D pattern-making.

Criteria for Play Materials

In order to access a wide range of competencies, the main study would need to incorporate play materials matched to each of the following criteria.

1. Materials providing for linear organisation by default but with the potential for attribute based sequencing and linear repeated pattern-making.
2. Materials with the potential for linear organisation, but not 2D spatial organisation or pattern-making; and with potential for attribute based sequencing and repeated pattern-making.
3. Materials with the potential for linear organisation, attribute based sequencing, repeated pattern-making, 2D spatial organisation and 2D pattern-making,

Pattern-making and Symbolic Play

During the first pilot study, a small group of children used play materials primarily to represent real or imaginative experience. Children worked symbolically with beads, collage materials and colouring grids. Earlier research (Gura 1992) highlights a group of children, described as 'dramatists' as opposed to 'patterners,' who are primarily motivated to use play materials for symbolic purposes. 'Dramatists' may choose to use any play materials imaginatively. However, adults conventionally encourage children to use collage and mark-

making materials for symbolic purposes. Therefore, to support mathematical rather than symbolic play, the main study would need to reject collage and mark-making materials, prioritising play materials with more limited symbolic associations.

Control of Materials

During the first pilot study some young children experienced difficulties and sometimes frustration when attempting to work with collage, paint and printing materials. In some cases, children's poor control of materials led to difficulties in the interpretation of patterning intentions. Additionally, some young children seemed to dislike the potentially messy nature of such activities and were reluctant to participate in activities.

Children do vary in terms of preferred play materials and preferences can change over time. Consequently, it is difficult to select play materials that are favoured by all. However, it seems appropriate to avoid materials with clear negative connotations for some children. To assess pattern-making competencies effectively, the main study would need to reject assessment materials that some children find messy and/or difficult to control.

Management Demands of Materials

A related methodological issue arises from the differing management demands of play materials. During the first pilot study, as children worked with paint, collage and printing materials, demands were often placed on the teacher-researcher to carry out such tasks as cleaning spilt paint and refilling paint pots. On occasions, the management demands of play materials interfered with the teacher-researcher's close observation of children's work. To ensure manageability, the main study would need to take account of this factor in the selection of assessment play materials,

Attributes of Materials

The first pilot study raised two further methodological issues, with implications for the selection of assessment materials for the main study. The analysis of some first pilot study data was problematic, as a result of either the ambiguity or the complexity of data. Ambiguity and complexity were related to the number and range of the attributes of play materials.

Ambiguity of Data

In the first pilot study, there were particular difficulties relating to the interpretation of children's intentions in contexts where play materials varied in only two or three ways across a single dimension. For example, where collage and printing materials varied across the single dimension of shape, with only two or three shapes used, intentions remained ambiguous, except where children made linear repeated patterns. Further problems arose in interpreting children's work with beads. Beads varied across the dimensions of colour and size, with just two sizes of

beads. Where children's attribute based sequencing focused on size, their intentions again remained ambiguous.

Complexity of Data

Additionally, because beads varied across the attributes of both colour and size, children made a particularly wide range of sequences, resulting in difficulties of comparability. The main study would need to guard against collecting ambiguous data as described above and highly complex data. To assess children's intentions in attribute based sequencing as well as repeated pattern-making, the main study would need to select play materials varying across just one dimension but in at least four ways.

Recording Processes and Products

To support the interpretation of children's intentions in patterning play, it is helpful to record both the process and the products of children's work. During the first pilot study, the recording of products took priority over the recording of process. As a result, children's patterning intentions remained ambiguous in several cases.

The ambiguity of much first pilot study data highlights the importance of recording firstly, evidence relating to the placement order of play materials; secondly, evidence relating to children's pre-selection or visual scanning of materials; and thirdly, details of children's language use. In considering assessment activities, the main study would need to reject any play materials where high management demands could interfere with such recording. In particular, the main study would need to prioritise the use of play materials with the potential for linear or 2D spatial organisation, facilitating the recording of placement order.

Play Materials and a Range of Evidence

The analysis of data from the first pilot study has highlighted a number of methodological issues relating to assessment materials, with implications for the selection of play materials for main study assessment activities.

However, despite the problematic nature of some materials, play materials were initially selected to reflect the range of materials with potential for patterning play and pattern-making in the nursery. Working with a narrowed range of play materials could result in firstly, underestimation of some children's competencies and secondly, underestimation of the range of patterning play and pattern-making undertaken by 3 and 4 year olds in a nursery setting. For these reasons, the main study would need to retain a focus on the wider range of opportunities for patterning play and for pattern-making available in the naturalistic setting of the nursery class.

ADULT SCAFFOLDING OF ASSESSMENT ACTIVITIES

The review of the first pilot study methodology has focused on firstly, the research strategy and secondly, the nature and range of assessment materials. The third and related aspect of methodology to be reviewed concerns the structuring of assessment activities in relation to levels of adult assistance or scaffolding.

Wood, Bruner and Ross (1976), to describe how a teacher ideally assists a child in carrying out a difficult task, first used the metaphor of scaffolding. Tharp and Gallimore (1988) explain how the concept of scaffolding was developed from Vygotsy's theoretical work relating to the zone of proximal development, defined as the distance between unassisted and assisted performance. Traditionally, developmental psychologists have used standardised tests of unassisted performance to assess developmental level. Tharp and Gallimore explain how the theoretical insights of Vygotsky have shaped a new approach to assessment, introducing a focus on the assessment of assisted performance or learning alongside the assessment of unassisted performance.

In a discussion relating to the issue of distance between assisted and unassisted performance, Meadows (1993) reviews the difficulties involved in diagnosing cognitive development. She highlights children's variability in performance in relation to apparently minor variations in task presentation. Meadows argues for the assessment of children across a range of tasks, with the criteria for variation clearly defined. She argues that a range of assessments can lead to more reliable diagnosis; can increase our understanding of the cognitive demands of tasks; and can lead to a deepened understanding of individual cognition. Meadows suggests that it may be particularly useful to assess children during training or when working collaboratively with someone more expert in a domain.

This discussion of assessment issues relating to contextual variation has implications for the following review of pilot study assessment activities.

Assessment Activities

In the review of research literature in Chapter 2, the learning context, as a variable influencing observed competence, was identified as an important area for further investigation. Contexts for learning were discussed primarily in terms of the attributes of play materials but more indirectly in terms of levels of adult assistance. Different kinds of adult assistance, for example, are provided in copying, continuing and devising activities.

The first pilot study incorporated the observation of children in contexts varying in both these ways. However, the observation across contexts was not systematically planned and most children were observed in only one or two contrasting contexts. Generally, as a consequence of the intention to replicate naturalistic adult-child interactions, there was a focus on assisted contexts in the first pilot study. Naturalistic interactions with this age group are likely to incorporate elements of scaffolding.

Levels of adult assistance

Assessment contexts varied during the first pilot study, with levels of adult assistance matched to one or more of the following criteria:

- open-ended activity - no adult assistance
- invitation to make a pattern - no adult assistance
- adult encouragement to sustain attention through praise and approval
- invitation to make a pattern - with a commentary on the patterned elements of an artefact
- adult modelling of pattern-making - with a commentary
- adult modelling of pattern-making - with no commentary
- adult modelling of pattern-making - with no model to copy or continue
- adult modelling of pattern-making - with a model to continue
- adult modelling of pattern-making - with a model to copy

The elements of adult assistance identified above match several of the elements identified by Wood, Bruner and Ross (1976) in their investigation into the effects of adult tutoring on young children's problem-solving. These key elements of adult assistance are firstly, 'recruitment' and 'direction maintenance', or eliciting and supporting children's engagement in a focus activity; secondly, 'marking critical features' of the task; and thirdly, 'demonstration' or modelling.

The elements of adult assistance identified above also differ in an important way from those described by Wood, Bruner and Ross. During the first pilot study, several elements of adult assistance were tied to specific activities, rather than being contingent upon children's observed performance.

The loosely structured variation across tasks, as outlined above, was appropriate to the exploratory phase of the research. However, the main study would need to assess children systematically across contexts varying in "a principled way" (Meadows 1993 p.346) in terms of levels or kinds of adult scaffolding. In structuring a smaller but more focused set of assessment activities, the main study would need to take account of the criteria for levels of adult assistance, as specified above. Levels of adult assistance for assessment activities would need to be defined by standardised procedures.

SUMMARY OF METHODOLOGICAL ISSUES AND IMPLICATIONS FOR THE MAIN STUDY

The key methodological issues raised by the first pilot study have been reviewed. The issues raised will be summarised below, with consideration given to the implications of these for firstly, the research strategy and secondly, the assessment tasks to be used in the main study.

The Research Strategy

In assessing the strengths and weaknesses of the diary study as used in the first pilot study, the key issues reviewed related to ecological validity, sampling, protocol, developmental change and individual differences. It was concluded that the main study would need to consider triangulation as a response to some of these complex methodological issues.

Ecological Validity

The ecological validity of assessment contexts was identified as a significant strength of the diary study. Despite associated problems, including threats to reliability, ecological validity was highlighted as an important feature of assessment contexts and one that would need to be retained within the main study research strategy.

Sampling

Sampling problems proved to be a particular weakness of the first pilot study. The problem of sampling 'reluctant patterners' was seen to be intrinsic to the research strategy and one closely associated with the ecological validity of assessment contexts. In order to sample 'reluctant patterners,' the main study would need to include a more structured approach to sampling.

The problem of sampling self-initiated patterning was seen as a different kind of problem and not one intrinsic to the methodology of a diary study. In order to sample self-initiated work, the main study would need to take a more focused approach than the first pilot study, although an approach still opportunist in nature. This suggests that the main study research strategy would need to retain a unstructured strand, but one focused on a smaller group of children.

Protocol

Reliability was the second problem associated with the high ecological validity of the diary study methodology. The main study would need to address problems of reliability resulting from a lack of standardised procedures or protocol.

Developmental Issues

Developmental issues were raised by the first pilot study, leading to a recognition of the need for the main study to ensure an effective strategy for tracking and describing early development towards and within pattern-making. The main study would need a cross-sectional strand to focus on the behaviours of 3 and 4 year olds as distinct groups and a longitudinal strand, to ensure a complementary focus on the changes in individual children over time.

Individual Differences

The first pilot study raised questions about the relationship between aspects of developing cognition and individual differences in patterning play and pattern-making competencies. To address these questions, the main study would need to identify and assess those aspects of developing cognition that might be associated with early patterning play and pattern-making competencies. The first pilot study also raised questions about the relationship between gender differences and differences in early patterning and pattern-making competencies. To address these questions, the main study would need to ensure systematic sampling.

Triangulation

As identified above, the use of triangulation was identified as an effective response to the difficult methodological issues raised by this review of the first pilot study. The main study would need to include two distinct strands. A mainly qualitative strand would retain the positive features of the diary study, in particular the ecological validity of assessment contexts and the sampling of self-initiated work. A second strand would need to be tighter, both in terms of sampling and in terms of the structuring of assessment contexts.

The Nature and Range of Assessment Materials

The second aspect of methodology to be reviewed was the nature and range of assessment materials used during the first pilot study. Issues raised related to:

- the potential of materials to facilitate children's demonstration of a range of early patterning and pattern-making competencies
- the suitability of materials for eliciting symbolic as opposed to symbolic play
- the relative attractiveness of play materials for young children
- the associated management demands of particular play materials
- the associated ambiguity and/or complexity of data yielded by play materials
- the manageability of play materials in relation to a researcher recording both process and product

Review of these issues led to specific criteria for the selection of play materials for main study assessments.

By working from the specific criteria detailed above, the main study would utilise a relatively narrow range of assessment materials. While this narrowing of assessment contexts would be appropriate for the structured strand of the research, the main study would need to incorporate a purely qualitative strand, allowing for the observation of children working with the full range of play materials available in the naturalistic setting.

Adult Scaffolding

The third aspect of first pilot study methodology to be reviewed was the structuring of assessment activities in relation to levels of adult assistance or scaffolding. First pilot study assessment contexts varied widely in terms of the levels of adult assistance provided. However, the main study would need to assess children more systematically across contexts, using the criteria for levels of adult assistance detailed above. Standardised procedures would be needed to define levels of adult assistance within the structured strand of the research.

IMPLICATIONS FOR THE MAIN STUDY

The first pilot study was successful in achieving its third aim, to support the planning of an appropriate research strategy and the methods and techniques to be employed in the main study. A review of the strengths and weaknesses of the diary study, as a research strategy, proved instrumental in raising general methodological issues pertinent to the main study.

To address the wide-ranging methodological issues discussed above, the main study would need to incorporate two distinct strands of research. The first strand, with closely structured assessment activities and controlled sampling, would provide data for a quantitative as well as qualitative analysis of the research questions. The second strand would be a solely qualitative strand, building on the strengths but refining the methodology of the diary study, as used in the first pilot study.

In the final section of Chapter 3, the structured assessment tasks for the mainly quantitative strand of the research are considered. Assessment activities are shaped by the main study research questions and structured in relation to the criteria arising from the review of key methodological issues.

THE SECOND PILOT STUDY

The first pilot study provided an exploratory context for firstly refining the main study research questions and secondly examining issues of methodology. The first pilot study prepared the ground for planning a research strategy, with appropriate methodology, to shape the main study.

Aims

The second pilot study was intended to build on the work of the first pilot study. Working with the refined set of research questions, the second pilot study was planned to achieve the following aims:

- to trial, evaluate and, where necessary, amend new pattern assessment activities for use in the main study.

- to trial, evaluate and, where necessary, amend a further set of assessment activities for use in the main study, relating to key aspects of early cognitive development

This final section of Chapter 3 begins with an outline of the methodology of the second pilot study. This outline includes details of firstly, the sample and secondly, the assessment activities trialled in the study. Following this, the pattern related assessment activities are discussed, with a focus on the rationale for the design of these activities. Next, the assessment of wider aspects of developing cognition is considered, with discussion again focused on the rationale for the design of activities. In the final section, the implications of the second pilot study outcomes for the main study are reviewed.

METHODOLOGY

The Sample

The sample for the second pilot study was selected from a population of children of 3½ and 4½ years attending two nursery classes in the same inner-city area. In the first nursery, also used in the first pilot study, 52 children attended for morning sessions and 52 children attended for afternoon sessions. The teacher-researcher was a member of the staff team at this nursery. In the second, smaller nursery, 39 children attended for morning sessions and 39 attended for afternoon sessions.

Sample children were selected from the class register in order to include a range of ages from 3 to 4 years. The sample from the first nursery was made up of 40 children aged between 3 years 4 months and 4 years 8 months. Children from this age range participated in the early assessment activities of the second pilot study. Some children participated in a single activity while some participated in several. For subsequent activities, two distinct groups of approximately equal size were selected, with ages in the range from 3 years 4 months to 3 years 7 months and 4 years 5 months to 4 years 8 months. This sample from the second nursery was made up of 9 children, from 3 years 6 months to 4 years 4 months.

Sampling for Pattern Assessment Activities

Small samples were used to trial pattern assessment activities. Sample size was as follows:

- Thirteen children from the first nursery, with ages ranging from 3 years 2 months to 4 years 8 months, participated in the Bead Threading activity.
- A group of nine children from the second nursery participated in the first Teddy's Beads activity. Three 4 year olds from the first nursery participated in a revised design of this activity.

- Sixteen children from the first nursery, including eight 3 year olds and eight 4 year olds, participated in the first Mosaic Tiles activity. Subsequently, a further fourteen children, similarly divided by age, participated in a revised design of this activity.
- Nine children from the first nursery, with ages ranging from 3 years 6 months to 4 years 4 months, participated in the first Pegs and Pegboard activity. The group of nine children from the second nursery also participated in this activity. Ten children from the first nursery, including five 3 year olds and five 4 year olds participated in a revised design of this activity. Subsequently, a further eight children from this nursery, including two 3 year olds and six 4 year olds, participated in a second revised design of this activity.

Sampling for Non-pattern Assessment Activities

Small samples were used to trial published assessment materials, designed to assess key aspects of cognitive development in this age group.

- The Pre-school Language Assessment Instrument (Blank et al. 1978) was used with three 3 year olds from the first nursery.
- Eye-hand and spatial ability assessment activities from the Manual for Assessment in Nursery Education (Bates et al. 1978) were used with eight children, including four 3 year olds and four 4 year olds from the first nursery.
- A replicating rhythmic sequences activity from the Manual for Assessment in Nursery Education (Bates et al. 1978) was used with two 4 year olds and two 3 year olds from the first nursery.
- Number assessment activities from the Manual for Assessment in Nursery Education (Bates et al. 1978) were used with a group of ten 3 to 4 year olds.

Small samples were used to trial assessment materials designed by the teacher-researcher.

- A number assessment activity was used with ten children, including five 3 year olds and five 4 year olds.
- A figure drawing assessment activity was used with the group of nine children from the second nursery.
- A colour matching and knowledge of colour words assessment was used with three 3 year olds and one 4 year old from the first nursery.

Pattern Assessment Activities

Designed to address the research questions relating to young children's pattern related competencies, the second pilot study included assessment activities incorporating three different

classroom materials with the potential for patterning play and pattern-making. The materials selected were threading beads; mosaic tiles used with linear bases; and pegs and pegboards.

Bead Threading

Beads were used in a simple threading activity. Children were invited to thread beads from a collection of cubes of one size and six colours. A protocol was followed, with children asked, "Can you do some nice threading with the beads?" Each child's bead sequence was recorded. Children's use of language during the activity was also recorded.

Teddy's Beads

A similar collection of beads and additionally four teddies was used in a set of activities involving different levels of challenge. This set of activities was incorporated within a story frame relating to the four teddies and their necklaces. Children were initially introduced to the teddies and invited to express a preference for one of three necklaces worn by the bears. Each necklace was made up of green and yellow beads. One necklace was made with an alternating pattern; one with a symmetrical pattern; and one with a random arrangement of beads. Children were asked to say what they liked about their selected necklace. Children were then invited to copy, continue and devise repeating patterns, responding to contrivances within the story frame. The model for the copying and continuing activities was a two colour alternating pattern. The invitation to devise a repeating pattern was open-ended. In an amendment to the set of activities, a second invitation to make a pattern was added. This invitation specified the use of three colours of beads, red, green and yellow.

Each child's bead sequences were recorded. Children's use of language during the activity was also recorded.

Mosaic Tiles

Squares in five colours from a collection of Duplo mosaic tiles were used with a Duplo strip. The strip allowed for the placement of twelve tiles. In the first version of this activity, children were asked, "What can you make with the squares?" Following this, an adult modelled making an alternating pattern with red and black tiles. Colours were named as the tiles were placed. The adult's pattern was then removed and children were invited to use the tiles again, with the question, "Can you make a pattern this time?"

In the amended version of this activity, children were first asked, "Can you make a pattern with the squares?" Following adult modelling of an alternating pattern, they were then asked, "Would you like to have another go to make a pattern?"

Children's mosaic tile sequences were recorded, with the placement order of tiles also recorded. Additionally, children's use of language during the activity was recorded.

Pegs and Pegboard

Pegboards and pegs in five colours were used in an open-ended activity. In the first version of the activity, children were invited to work with the pegs with the adult request, "Come and make something nice with the pegs." In the first revised version, they were invited with the request, "Come and make a pattern with the pegs." The second revision rephrased this request as a question, "Can you make a pattern with the pegs?"

The positioning of pegs and placement order were recorded. Where children paid attention to the colour of pegs in their selection, peg colour was also recorded. Additionally, children's use of language during the activity was recorded.

Additional Assessment Activities

Designed to address the research question relating to individual differences in development, the second pilot study trialled assessments of key aspects of cognitive development to index against pattern-making competencies. The key areas of early cognitive development identified as relevant to the study were language, number and spatial thinking. The following were identified as potentially useful additional measures; abilities in the replication of rhythmic sequences; colour matching skills and knowledge of colour names; and drawing skills.

Language

Blank's 'Pre-school Language Assessment Instrument' was used to assess language skills. This was specifically designed "to assess children's skills in coping with the language demands of the teaching situation" (Blank et al. 1978). Administration of the test followed the manual guidelines.

Number

Number assessment activities from the Manual for Assessment in Nursery Education (Bates et al. 1978) were used with a first group of children. Following this, a set of number assessment activities was designed, based on studies by Gelman and Gellistel (1978) and Fuson (1988).

Spatial Abilities

Eye-hand and spatial ability assessment activities from the Manual for Assessment in Nursery Education (Bates et al. 1978) were used.

Rhythmic Sequences

A replicating rhythmic sequences activity from the Manual for Assessment in Nursery Education (Bates et al. 1978) was used.

Drawing

A figure drawing assessment activity was used. Scoring was related to a sequence of developmental stages, based on the research of Cox (1992), Matthews (1993) and Fenson (1985).

Colour Matching and Colour Names

A simple colour matching and knowledge of colour words assessment was designed.

METHODOLOGICAL ISSUES

The key methodological issues arising from the first pilot study, in terms of research strategy, were ecological validity, sampling, protocols, the tracking of development over time, individual differences in development and triangulation. The second pilot study provided a context for the further investigation and clarification of all these issues, except one. The exception was the developmental issue.

Further methodological issues arising from the first pilot study related to firstly, the nature and range of play materials to be used and secondly, the structuring of assessment activities in relation to levels of adult assistance or scaffolding. The second pilot study provided a context for the further investigation and clarification of these issues.

Sampling Issues: Reluctant Patterners

Analysis of methodological issues arising from the first pilot study highlighted sampling as a particular weakness of the diary study methodology. A group of children described as 'reluctant patterners' in the first pilot study, children who were not attracted by focus activities, was poorly sampled in this study. This group was mainly comprised of 3 year olds, boys and probably children with relatively low levels of pattern-making competence. To sample these children, a more structured approach to sampling was used in the second pilot study.

Approximately equal numbers of boys and girls, as well as approximately equal numbers of 3 and 4 year olds were selected for the second pilot study sample. The sampling method used for the second pilot study ensured that the selected sample was representative of the nursery class population.

To ensure the willing participation of these children, the teacher-researcher was sensitive to children's interests when timing invitations to participate in assessment activities.

Additionally, children in their first few weeks at nursery were excluded from the sample. No children refused invitations or showed reluctance to participate in assessment activities during the second pilot study. A small number of the youngest children worked just briefly with the pegs and pegboard and with the Teddy's Beads activities. They were encouraged to return to other nursery activities as soon as their interest in the assessment activity waned.

The Nature and Range of Assessment Materials

In the first pilot study, activities utilising a wide range of play materials were used to explore a broad research focus on children's pattern-making activity. Analysis of a rich set of data from the first pilot study supported the refining of a broad research focus into a set of specific research questions. In the second pilot study, play materials were selected for assessment activities focused on these more specific research questions.

Play Materials Criteria

Clear criteria were needed to select materials that would support an investigation of the main study research questions. Following the first pilot study, the following criteria were framed to ensure sampling of the necessary range in terms of children's patterning play and pattern-making competencies:

1. Materials providing for linear organisation by default but with the potential for attribute-based sequencing and repeated pattern-making
2. Materials with the potential for linear organisation but not 2D spatial organisation or 2D pattern-making; and with the potential for attribute-based sequencing and repeated pattern-making
3. Materials with the potential for linear organisation, attribute-based sequencing, repeated pattern-making, 2D spatial organisation and 2D pattern-making

Additionally, the following criteria, used in the evaluation of play materials in the first pilot study, were used to select play materials for use in the second pilot study:

- suitability for eliciting patterning as opposed to symbolic play
- manageability in relation to the recording of both process and product.

Further criteria, used for the evaluation of play materials in the first pilot study were used in the second pilot study. These criteria, in particular, related to the study's 'usability', a feature of research design to be considered alongside validity and reliability (Goodwin and Goodwin 1993).

- attractiveness to young children
- associated management demands
- associated ambiguity and/or complexity of the data yielded

The Second Pilot Study Play Materials

The range of play materials used in the first pilot study was significantly narrowed for this second study. The play materials selected for pattern-making assessment activities in the second pilot study were threading beads, cubes of one size in six colours; mosaic squares, in five colours, with a linear base; and pegs in five colours with a pegboard. These play materials

provided a match to the three numbered criteria listed above. They also met all the additional criteria.

Although the pegs and pegboard assessment activity yielded more complex data than other activities, the inclusion of this activity was considered to be essential to the full exploration of the research questions.

Interrelated Issues: Ecological Validity, Reliability and Protocols

Ecological Validity

In the analysis of the first pilot study, ecological validity was highlighted as an issue of particular significance to researchers working with young children. Reference was made to a tradition of research in early childhood education in England, traced back to the work of Susan Isaacs in the 1920s, and founded on the view that naturalistic contexts support children in demonstrating competencies. More recently, Meadows (1993, p.347) has argued, from a wider perspective, that the diagnosis of cognitive development in childhood is supported by the recognition that cognition is “developed in social contexts, even ... constituted by social contexts.” She too argues for the study of children’s behaviour situated in well described social contexts.

To maximise ecological validity, pattern related assessment activities in the second pilot study were designed to closely parallel the naturalistic context of an adult and child working together during a nursery session. Consequently, there were often other children engaged in similar activities alongside the teacher-researcher and target child. Activities were presented to children as ‘everyday’ adult focus activities carried out during the main nursery session, rather than as special assessment activities. However, the more extended Teddy’s Beads activity elicited such a high level of interest from other nursery children that the location and timing of the activity were reviewed. Following this review, on some occasions the assessment took place in a small room continuously accessible during the main nursery session, but for just small numbers of children. On other occasions, the assessment took place in the main nursery classroom, but when most children were engaged in an end of session story-time.

The use of two contrasting nursery contexts in the second pilot study highlights the ways that a teacher-researcher can contribute to the ecological validity of assessments. In the first setting, working with a familiar adult, the responses of children to assessment activities mirrored their responses to everyday nursery activities. With the exception of children engaged in the Teddy’s Beads activity, children working with the teacher-researcher did not appear to perceive the activities as special. However, children in the second setting, working with the researcher as a visitor, seemed to have a greater awareness of the unusual status of activities. One child from the second nursery displayed a higher level of diffidence than was shown by any children from the teacher-researcher’s own nursery.

Reliability

The first pilot study focused on observations of children working in a naturalistic setting and ecological validity was a strength of this study. However, although the observational methodology of the diary study was valued as a strand to be retained within the main study, it was seen to be associated with significant difficulties. In particular, the use of naturalistic settings was associated with a lack of reliability in assessment data.

Goodwin and Goodwin's (1993 p.445) definition of reliability states that, "The reliability of a measure concerns the accuracy or consistency of the scores it yields." To ensure a level of reliability that would support an investigation of the main study research questions, standardised procedures were planned for the key assessment activities of the second pilot study. As protocols were devised, aspects of the authentic pupil-teacher relationship, in particular the teacher's spontaneity and responsiveness, were tightly controlled or written out of assessment activities. Inevitably, while increasing reliability, this approach detracted from the ecological validity of the second pilot study.

In the second pilot study, there was some evidence to support the reliability of assessments. With samples from two nursery classes, it was possible to compare children's responses to the subset of assessment activities used in both settings, the Teddy's Beads activity, the Pegs and Pegboard activity and the drawing activity. Analysis of data arising from this subset of activities provided evidence of a similar range of responses from the children in the two settings.

Further evidence to support the reliability of one assessment came from the assessment activity that was repeated with a small group. Eleven children were invited to thread beads on three or four occasions within the period of approximately one month. Seven of the children responded in similar ways to each request, for example sequencing sets of beads that were sorted by colour on each occasion. The other children responded in similar ways on at least two occasions. Some variability in the performance of some children indicated that this was not an assessment activity to use in isolation. However, despite some variability, the level of consistency in the responses of the majority of children indicated that this was a useful assessment to use as one of a group of assessments with a similar focus.

Protocols

Adult language is a key element of assessment protocols. Adults can use language supportively, to scaffold children's performance (Wood, Bruner and Ross 1976). The language used by adults can also contribute to children's difficulties in assessment contexts, for example in the Piagetian assessment contexts reviewed by Wood (1998).

The researcher's use of language was considered carefully in devising assessment protocols for the second pilot study. In particular, the researchers use of the word 'pattern' was

examined. There was initial concern that the use of the word 'pattern' might confuse some children.

During the second pilot study, assessment activities were used with different protocols, both with and without use of the word 'pattern.' Following the comparison of responses to different versions of the protocol, the word 'pattern' was identified as supportive for some children, encouraging responses based on mathematical rather than imaginative thinking. Some children's explicit questioning of the word 'pattern' also provided interesting data relating to children's developing concepts of pattern. This provided further support for the decision to incorporate the word 'pattern' within assessment protocols.

In writing and revising protocols for assessment activities, careful consideration was given to other aspects of wording and their effects on children's behaviour. For example, pattern activity protocols incorporating a direct request, "Come and make something nice..." were changed into invitations to accept a challenge, "Can you make a pattern with...?" In working with this age-group, the initial statement, in the form of a direct request, seemed more likely to invite non-compliance than did the questioning approach. Additionally, the challenging invitation was closer to the pattern of adult-child interactions in a nursery session than was the direct request.

As far as possible, attention was paid to ecological validity in designing protocols. Although the protocols were tightly structured, three of the four pattern assessment activities were designed to incorporate the naturalistic features of everyday play contexts, using mathematical play materials. The fourth activity, based on a story about four teddies, was more obviously 'special.' However it retained ecological validity, in so far as, like the 'naughty teddy' game in McGarrigle's study (Donaldson 1978), it mirrored the imaginative play and story contexts that were a familiar feature of nursery life.

Protocols place tight restrictions on the possibility of responsive interactions between adults and children. However, because many young children have an expectation of responsive interactions with adults, they continue to ask questions or express puzzlement in assessment contexts. During the second pilot study, the researcher's use of the word 'pattern' provoked questioning or puzzled responses from a minority of the children. It was necessary to have a protocol to respond to such questioning. As in a naturalistic setting, children were supported with a simple explanation of the word's meaning. However, unlike the adult in a naturalistic setting, the researcher provided a scripted explanation and could not be responsive to the further questioning that sometimes followed.

Adult Scaffolding of Pattern assessment Activities

The first pilot study identified adult scaffolding as a significant contextual variable. However, while adult scaffolding of pattern-making activities was identified as a significant variable, it was acknowledged that the effects of scaffolding could be complex. The second pilot

study defined levels of adult assistance to children engaged in assessment activities in a more standardised way than the first pilot study. Assessment activities were planned to include different kinds and levels of adult support, both for repeated pattern-making and for the spatial organisation of play materials.

Repeated Pattern-making

The Bead Threading activity provided no adult support beyond the use of the word 'pattern' in the invitation to participate in the activity. The Teddy's Beads activities offered variety in the kinds of assistance provided to support pattern-making. The first activity offered the model of a two colour, alternating pattern to be copied and the second activity offered a similar model to be continued. The third activity was an open-ended invitation to make a pattern, similar to the first Bead Threading activity. However, the use of the word 'pattern' in this invitation was set in the context of previously presented models of repeated patterns. In the fourth activity, a low level of adult support for pattern-making was provided. A prompt was given to use three specified colours for the pattern, and a bead of each colour was shown as it was named.

The mosaic tiles activity was designed to assess children's responses to an initial invitation to make a pattern, with no adult support provided. Following the child's first attempt, the researcher, who modelled the making of an alternating pattern, scaffolded the activity. The red and black tiles were named as tiles were placed. The model, however, was not left for children to copy.

Spatial Organisation

In the mosaic tiles activity, the researcher modelled the linear organisation of tiles. Tiles were placed next to each other along the strip, moving from one end of the strip to the other. In the pegs and pegboard activity, there was no scaffolding of the activity by the researcher.

Individual Differences

The first pilot study raised questions about the relationship between particular aspects of developing cognition and differences in the development of early patterning and pattern-making competencies. It raised questions about a possible relationship between differences in children's number concepts, counting skills and their developing pattern-making competencies. Findings also raised questions about a possible relationship between individual differences in productive language skills and developing pattern-making competencies. Finally, questions were raised about the possibility of a relationship between other aspects of young children's cognition and their developing pattern-making competencies.

Analysis of the first pilot study led to the identification of a need for specific main study assessments of children in areas of cognition considered likely to be associated with the

development of pattern-making competencies. In the section that follows, these areas and the key features of assessments trialled during the second pilot study are outlined.

Language

There may be a significant relationship between language development and a range of developing cognitive abilities, including aspects of early patterning and pattern-making competencies. Cromer (1991), reviewing the complex research literature focused on the relationship of language and thinking, cites a number of research studies evidencing the important role of language in shaping or supporting developing cognition.

During the second pilot study, Blank's 'Pre-school Language Assessment Instrument' designed for use with children from 3 to 6 years, was used to assess language skills. This was specifically designed "to assess children's skills in coping with the language demands of the teaching situation" (Blank et al. 1978 p.1). The assessment focuses on children's abilities to respond to language demands at varying levels of abstraction.

Despite its low ecological validity, Blank's assessment instrument was selected for the following reasons. Firstly, the assessment instrument focuses on an aspect of language that is particularly relevant to the research questions of the main study, children's language skills in a teaching context. Secondly, it yields a numerical score, with guidance relating to the interpretation of scores. Thirdly, it provides statistical information relating to reliability and validity.

Number

The first pilot study identified children's counting skills and number concepts as likely to co-vary with developing pattern-making competencies. In the second pilot study, number assessment activities from the Manual for Assessment in Nursery Education (Bates et al. 1978) were trialled with a small group of children. This assessment proved to be unsatisfactory for a number of reasons. Several children were reluctant to continue with activities; the focus of several assessment was on children's understanding of mathematical language generally and not on number language; and scores were tightly clustered with scores failing to discriminate between children who the teacher-researcher knew to have different levels of counting skills.

Following evaluation, a further set of number assessment activities was trialled, drawing on the work of Gelman and Gallistel (1983) and Fuson (1988). This set of activities focused on subitising, counting skills to ten, cardinality and conservation. Assessment activities incorporated the use of a teddy bear and small toys to be shared on two plates, one for the child and one for the teacher-researcher. Although sharing was not the focus of assessments, the sharing theme provided an imaginative and therefore motivating context for children. Assessments were enjoyed and scores discriminated effectively between children.

Spatial Abilities

The second pilot study focused on spatial abilities, as abilities likely to co-vary with developing pattern-making competencies. Researchers in the psychometric tradition have extensively studied spatial abilities, as a component of an hypothesised stable intelligence. At times spatial abilities have been considered as a part of a general cognitive ability and at times as a more specific ability (Meadows 1993). More recently, researchers in the information processing tradition, for example Anderson (1992) have considered spatial abilities as in part determined by a specific processor, varying in speed from individual to individual.

In the second pilot study, to achieve measures of children's spatial abilities, eye-hand and spatial ability assessment activities from the Manual for Assessment in Nursery Education (Bates et al. 1978) were trialled. These assessment activities used blocks and jigsaws, familiar nursery play materials. They were enjoyed by the children and were manageable to use. Scores discriminated effectively between children.

Musical Patterns

The second pilot study identified rhythmic abilities as likely to co-vary with developing pattern-making competencies. Some maths schemes and resource books for early years teachers assume a relationship between musical, rhythmic abilities and mathematical pattern-making, and they include repeated pattern work with sounds (Beginnings 1967; Beam 1997).

To provide a measure of this ability, a replicating rhythmic sequence activity from the Manual for Assessment in Nursery Education (Bates et al 1978) was trialled in the second pilot study. Although a difficult activity for many 3 year olds, this was an enjoyable activity for all children and one that provided a useful range of scores for 4 year olds.

Drawing

The second pilot study focused on children's drawing abilities as abilities likely to co-vary with the spatial aspects of developing pattern-making competencies. In Chapter 2, a reported study by Booth (1981) focused on the early development of mark-making skills, identifying common roots for representational mark-making and pattern-making with paint. Although the Goodenough 'Draw a Man Test', as revised by Harris (1963), has been consistently used by teachers and researchers as a measure of intellectual maturity, its use for the second pilot study was rejected. The Goodenough-Harris scoring system was rejected for a number of reasons. This scoring system is related to the assessment of a hypothesised general intelligence, rather than cognitive processes that may be specific to drawing ability. As Cox notes (1992) the scoring system focuses on children's inclusion of detail at the expense of other significant aspects of development, for example structure. The scoring system was also rejected because it was not age-appropriate. It fails to discriminate early development in pre-representational drawing skills.

However, the drawing assessment activity used in the second pilot study was similar to that used by Goodenough. Children were asked to draw a picture of themselves, rather than a man. Attempts were made to overcome the problems of reliability noted by Cox (1992) by using several strategies to encourage a “best effort” drawing. As a teacher-researcher, it was possible to assess where a child’s drawing fell significantly short of a best effort.

A nine stage scoring system was developed, based on the work of a number of researchers (Arnheim 1969; Goodnow 1977; Fenson 1985; Athey 1990; Cox 1992; Matthews 1993). Children’s work was categorised in relation to the most advanced features of drawings. The scoring system is outlined in Appendix 1.

Colour Names and Matching Skills

The second pilot study focused on colour naming and colour matching skills as skills likely to co-vary with developing pattern-making competencies. A simple colour matching and knowledge of colour words assessment used beads in six colours, as in several pilot study assessment activities.

MOVING INTO THE MAIN STUDY

The issues raised by reviews of the historical background to the study and the research literature prepared the ground for the two pilot studies presented in this chapter. Informed by the historical review, the review of research literature led to the identification of significant gaps and areas of weakness in the research base informing approaches to pattern in recent curriculum guidance for the foundation stage. This led to the delineation of a broad area of focus for research. The literature review also raised methodological issues, in particular issues relating to the assessment of young children.

The first pilot study explored the broad research focus on the pattern-making activity of 3 and 4 year olds, undertaking this in the naturalistic setting of a nursery class. Analysis of the findings from this study supported the process of refining a broad research focus on young children’s pattern-making into a set of specific research questions for the main study. The first pilot study also raised a number of methodological issues. An examination of these issues supported the planning of an appropriate research strategy and the methods and techniques to be employed in the main study

With the research questions defined and a research strategy in place, the second pilot study carried the research forward, trialling specific assessment activities to be used in the main study. These were a range of pattern assessment activities and a further set of assessment activities relating to key aspects of cognitive development. The first and second pilot studies, with their distinct aims and methodologies, prepared the ground for the main study, to be presented in Chapter 4.

CHAPTER 4

THE MAIN STUDY

The issues raised by a review of the historical background to the study, a review of the research literature and the analysis of two pilot studies shaped firstly, the research questions informing the main study and secondly, the methodology to be used in this study. This chapter begins with a restatement of the main study research questions and it then presents a summary of the ways that issues raised by the two pilot studies informed the methodology of the main study. Following this, the methods and techniques employed in the investigation of the main study research questions are presented. The details of research design, including the size of samples, the selection of samples, methods of data collection and methods of analysis are outlined.

INTRODUCTION

Issues raised by the first pilot study informed the framing of the research questions for the main study. The first pilot study explored a broad research focus on children's pattern-making activity in a nursery setting. It contributed to the process of refining the initially broad research focus on young children's pattern-related competencies into a set of specific research questions, restated below:

1. What knowledge, understanding and skills in pattern-making do children demonstrate at 3½ and 4½ years of age?
2. Where do knowledge, understanding and skills in pattern-making begin and how do they develop between the ages of 3½ and 4½ years?
3. Are there individual differences in the detailed pathways taken towards knowledge, understanding and skills in pattern-making?
4. Are there individual differences in knowledge, understanding and skills in pattern-making and in rates of development between 3½ and 4½ years?
5. Do individual differences in the development of knowledge, understanding and skills in pattern-making relate systematically to differences across other dimensions of development?

The first pilot study also raised a range of methodological issues relating to the research strategy and methods of data collection to be employed in the main study. The main issues raised were those of construct validity, the related issues of reliability and ecological validity, as well as issues of sampling, protocols, the tracking of development over time, individual differences in development and triangulation. Examination of the issues contributed to the process of planning an appropriate research strategy for the main study, as well as the methods and techniques to be employed in this study.

The second pilot study took forward the work of the first pilot study. Working with the refined set of research questions, the second pilot study was used to trial, evaluate and amend as

necessary pattern assessment activities for use in the main study. It was also used to trial, evaluate and amend as necessary assessment activities relating to other key aspects of early cognitive development.

Given the breadth of main study research questions and the potential complexity of the qualitative data to be collected, research questions were prioritised. While it was considered important to consider some issues in depth, it was considered appropriate to examine other questions in a more restricted way. The main thrust of the study was an examination of the first two questions. The issues raised by questions three, four and five would need to be considered but considered briefly.

METHODOLOGY

Cross-sectional and Longitudinal Studies

In order to examine the knowledge, understanding and skills in pattern-making of children at particular points in time as well as of children over time, two discrete but closely related studies were undertaken. The first was a cross-sectional study with two distinct samples of children at 3½ and 4½ years. This study focused on children's knowledge, understanding and skills in pattern-making at the two specific ages. The second study was a longitudinal study, focused on tracking children's development towards and within pattern-making over time from 3½ to 4½ years.

Ecological Validity and Reliability

Acknowledging the complex and interrelated issues of ecological validity and reliability (Coolican 1990), the main study incorporated two main approaches to the collection of data. Data were collected firstly in the context of adult directed assessment activities and secondly, in the context of child initiated play activities.

The data collection methods for adult directed assessment activities were shaped by clear protocols. These contributed to the reliability of specific assessments. Additionally, to increase the overall reliability of the study, assessment activities focused on different aspects of pattern-making were included (Meadows 1993).

To provide a degree of ecological validity alongside reliability, the pattern-related assessment activities and the related protocols were designed to replicate key features of the naturalistic setting of the nursery class (Coolican 1990). There were, however, two key features of the naturalistic setting that could not be replicated in main study assessment activities. These were firstly, the spontaneity of adult responses to children's interactions and secondly, the self-directed quality of much of the work undertaken by children in naturalistic settings. The second approach to data collection was necessary because of the problematic nature, in terms of ecological validity, of adult directed assessment activities. To provide a balanced approach to the

assessment of young children's pattern-related competencies, the main study included a solely qualitative strand. Observational data, with a main focus on children's spontaneous pattern-making and patterning play, was collected in the naturalistic context of the nursery class.

Construct Validity

The two contrasting approaches to the collection of main study data were also important to the consideration of construct validity (Robson 1993). 'Pattern', as a mathematical concept, is a concept with wide application. An underlying aim of the study was to define the range and limits of this concept in terms of its applicability to the competencies of young children. A narrow focus on a small number of assessment activities could have restricted the competencies evidenced by the study. To sample possible competencies beyond the range of those formally assessed, data was collected in informal as well as more formalised assessment contexts.

Triangulation

A multi-method approach, using a range of formalised assessment activities as well as observational data collected in the naturalistic setting, provided for triangulation (Cohen and Manion 1989). Triangulation is important in planning to reduce the effects of particular methods of data collection on the results obtained (Cohen and Manion 1989).

It was recognised that formalised data collection methods could create anxiety for some children, leading to a possible underestimation of competencies. Additionally, it was recognised that formalised data collection methods could lead to the underestimation of some children's competencies, resulting from their lack of engagement with adult led activities. The use of observational data collection methods, focused on children's self-initiated play, made it possible to access children's competencies in those naturalistic contexts where children are most likely to be confident, self-motivated and consequently most fully engaged in their play (Pascal and Bertram 1997).

Triangulation is also important when there is a need to investigate different but complementary research questions (Robson 1993). The five research questions were clearly complementary but with different foci, requiring different approaches to the collection of data.

Finally, the use of multiple methods enhanced the interpretability of the main study (Robson 1993). Formalised assessment activities provided quantitative data, while observational methods provided qualitative data. Statistical analyses were important to the investigation of the first and fifth research questions, with some additional support provided from qualitative accounts of children's pattern-related competencies. In contrast, primarily qualitative analysis was important to the investigation of the second, third and fourth research questions, with additional support provided by statistical analysis.

THE CROSS-SECTIONAL STUDY

The aim of the cross-sectional study was to provide data to examine the two research questions below:

1. What knowledge, understanding and skills in pattern-making do children demonstrate at 3½ and 4½ years of age?
5. Do individual differences in the development of knowledge, understanding and skills in pattern-making relate systematically to differences across other dimensions of development?

The Sample

The sample came from a population of children of 3½ and 4½ years attending an inner-city nursery class which served a predominately white UK community. Fifty-two children attended the nursery for five morning sessions a week and the same number attended the nursery for five afternoon sessions a week. The teacher-researcher was a member of the staff team at the nursery. The process of selection simply involved selecting all children on the class register as they attained the relevant ages, 3½ and 4½ years. Only the small number of children who had recently joined the class and were not yet settled were excluded from the sample. The sample at 3½ years comprised 50 children in the age group from 3 years 5 months to 3 years 7 months. Twenty-four children from this group were also included in the sample at 4½ years. In total there were 49 children in the sample at 4½ years, with ages ranging from 4 years 5 months to 4 year 7 months.

Pattern-related Assessment Activities

To examine the first research question relating to children's knowledge, understanding and skills in pattern-making at 3½ and 4½ years, a range of pattern-related assessment activities were undertaken. Assessment activities incorporated three different classroom materials. This range of materials provided for the possibilities of both linear and 2D pattern-making or patterning play. The materials selected were threading beads; mosaic tiles used with linear bases; and pegs and pegboards. Colour was the sole varying attribute of the selected play materials.

One assessment activity, using threading beads, focused on children's knowledge and understanding about pattern and their competencies in articulating this understanding. All other assessment activities focused on children's skills in copying, continuing and devising patterns.

The first copying activity focused on children's skills in copying a physical model made with beads. The second copying activity focused on children's skills in copying a linear sequence of mosaic tiles, first modelled by the adult and then removed. In this second assessment activity, copying was of a memorised sequence. The devising assessment activities included open-ended invitations to make patterns, as well as an invitation to devise a pattern with three specified colours. The following assessment activities focused on children's pattern-related competencies were used.

Bead Threading

This assessment activity utilised beads in a simple threading activity. Children were invited to thread beads from a collection of cubes of one size and six colours. A protocol was followed, with children asked, “Can you make a pattern with the beads?” Each child’s bead sequence was recorded. Evidence of active searching behaviours and pre-selection of materials was recorded. Additionally, children’s use of language during the activity was recorded. The protocol for the adult’s response to a child’s request for clarification of the meaning of ‘pattern’ can be found in Appendix 2.

Teddy's Beads

This set of assessment activities used a similar collection of beads to that used in Bead Threading. Additionally four teddies were used. The set of activities was incorporated within a story frame relating to the four teddies and four bead necklaces. Children were initially introduced to the teddies, three of which were wearing necklaces. The children were invited to express a preference for one of the three necklaces. Each necklace was made up of green and yellow beads. One necklace was made with an alternating pattern; one with a symmetrical pattern; and one with a random arrangement of beads. Having chosen a necklace, children were then asked what they liked about their selected necklace.

Following this introductory activity, children were invited to use beads to copy, continue and devise repeating patterns, responding to contrivances within the story frame. The model for the copying and continuing activities was an alternating pattern. The invitation to devise a pattern for a fourth necklace for Baby Bear specified the use of three colours of beads, red, green and yellow.

Each child’s bead sequences was recorded. Active searching behaviours and pre-selection of materials were also recorded. Additionally, children’s use of language during the activity was recorded. The protocol for this assessment is reported in Appendix 2.

Mosaic Tiles

In this activity, squares in five colours from a collection of Duplo mosaic tiles were used in conjunction with a duplo strip. The strip allowed for the placement of twelve tiles. Children were first asked, “Can you make a pattern with the squares?” Following each child’s first attempt, an adult modelled the making of an alternating pattern with red and black tiles. Colours were named as the tiles were placed. The adult’s pattern was then removed and children were invited to use the tiles again, with the question, “Would you like to have another go to make a pattern?”

Children's mosaic tile sequences were recorded, with the placement order of tiles also recorded. Active searching behaviours and pre-selection of materials were recorded. Additionally, children's use of language during the activity was recorded. The protocol for the adult's response to a child's request for clarification of the meaning of 'pattern' can be found in Appendix 2.

Pegs and Pegboard

In this activity pegboards and pegs in five colours were used. Children were invited to work with the pegs with the open-ended adult request, "Can you make a pattern with the pegs?" The positioning of pegs and placement order was recorded. Where children paid attention to the colour of pegs in their selection, peg colours were also recorded. Active searching behaviours and pre-selection of materials were recorded. Additionally, children's use of language during the activity was recorded.

The protocol for the adult's response to a child's request for clarification of the meaning of 'pattern' can be found in Appendix 2.

Additional Assessment Activities

Additional assessment activities were undertaken to support examination of the fifth research question, focused on the possibility of systematic relationships between individual differences in children's knowledge, understanding and skills in pattern-making and their development across other areas of cognition. Measures of children's cognitive development were taken to index against children's early patterning and pattern-making competencies. The key areas of early cognitive development identified as relevant to the study were language, number and drawing; spatial thinking; abilities in the replication of rhythmic sequences; and colour matching with the associated knowledge of colour names. The six assessment activities relating to these areas of developing cognition are outlined below.

Language

Blank's 'Pre-school Language Assessment Instrument' was used to assess children's language skills. Administration of the test followed the manual guidelines. This assessment instrument was specifically designed "to assess children's skills in coping with the language demands of the teaching situation" (Blank et al: 1978, p.1). It was designed for use with children from three to five years of age, focusing on the ability of children to use language to represent and understand increasingly complex ideas. The assessment activities took the form of adult questioning about pictures of objects and scenes, as well as questioning about described scenarios.

Each assessment item in this assessment instrument is designed to elicit a response at one of the four levels identified below:

- Level 1 - matching language to experience
- Level 2 - selective analysis of experience
- Level 3 - reordering of experience
- Level 4 - reasoning about experience

The four levels represent a hierarchy of demands on the child in terms of the increasing complexity and abstraction of language use. For example, at Level 1, children are shown a picture of a seated lady drinking from a cup and asked what she is doing. At Level 2, children are shown a picture of five scissors and asked to indicate the one that is 'big and closed'. A Level 3 question asks children to say how an illustrated knife and a pair of scissors are the same. At Level 4, children are shown a picture of a pile of cotton reels and asked what would happen to the pile if one cotton reel, with the bottom one indicated, is taken away.

In the main study, children's discrete scores at each level were aggregated as a composite score.

Number

A group of three number assessments were used. These are outlined below. The first assessment was adapted from an assessment activity devised by Gelman and Gallistel (1978). In order to maximise children's engagement with the activity, the following changes were made to the original schedule. The number of trials was reduced; changes were made to the wording of some instructions; and a teddy was substituted for the adult as the second recipient of toys. In this first number assessment children were presented with two plates with sets of small wooden toys, one plate for a teddy and one for themselves. The sets of wooden toys were of set sizes 2 and 3, 4 and 5, 7 and 10 in turn.

In the main study there were two trials for each set size, one trial with a linear arrangement and one trial with a non-linear arrangement of toys. Children were asked, "How many?" in relation to each set presented. Evidence of subitising or counting was recorded. If children did not count the toys initially but stated a number, they were then asked to count the toys. A record was made of firstly children's use of one to one correspondence in matching spoken numbers to objects. Secondly, children's knowledge of the number sequence was recorded. Finally, in order to assess children's understanding of cardinality, children were asked after counting the toys, "So how many is that?" The scoring system credited children for skills in subitising (Frobisher et al 1999); for their knowledge of the number sequence; and for evidence of an understanding of cardinality.

The second assessment, focused solely on children's cardinal number concepts, was based on Fuson's (1988) work. Children were asked to place toys on their own plate and the teddy's plate in turn. The specified set sizes were 2,3,4,5,7 and 10.

The third assessment was based on Piaget's (1952) conservation experiment. Children observed as two rows of buttons were placed in two lines in one to one correspondence. The children were then asked, "Are there more red buttons or more yellow buttons or just as many red as yellow buttons?" Following this, one row of buttons was spread out and the question repeated. Finally, after responding to this question children were asked, "How did you know that?" The scoring system credited children for an initial recognition of equivalence and for recognition of equivalence following the rearrangement of buttons. Additionally the scoring system credited children for a justification of a correct conservation judgement evidencing recognition that no action had been undertaken to change the numerosity of the sets.

Spatial Abilities

Eye-hand and spatial ability assessment activities from the Manual for Assessment in Nursery Education (Bates et al. 1978) were used. The first set of assessments focused on children's responses to four jigsaws at increasing levels of difficulty, from a five piece inset board to a twenty-five piece interlocking jigsaw. Children's responses at the four different levels were scored. The range of responses identified was trial and error, visual matching and use of definite strategies, such as looking for edge pieces.

The second set of assessments focused on the children's responses to tasks using wooden blocks. Following the adult's modelling of construction with blocks, children were asked to build a road, build a tower and to build steps. Scoring was based on the three or four different levels of competency outlined for each task.

Rhythmic Sequences

A replicating rhythmic sequences activity from the Manual for Assessment in Nursery Education (Bates et al. 1978) was used. Children were asked to listen to a short story, with simple rhythmic accompaniments provided for four repeated phrases. These occurred at regular intervals within the story. The story was then repeated and children were asked to beat the rhythm to the two pairs of repeated sequences. The two pairs of sequences were of increasing difficulty. In the scoring of children's responses to each pair of rhythms, four levels of competency were identified.

Drawing

A figure drawing assessment activity was used. The children were asked to draw a picture of themselves and were given a fine black felt pen and A4 paper. The scoring system related to a devised sequence of developmental stages from early mark-making through to figurative drawing, based on research evidence reported in Cox (1992), Matthews (1993) and Fenson (1985). It is presented in Appendix 1.

Colour Matching and Colour Names

A simple colour matching and knowledge of colour words assessment was used. Children were asked to find matching beads for beads of six colours and were then asked to name the colours. Children were scored for each response.

Data Analysis

The First Research Question

To investigate the first aspect of the first research question, qualitative data, exemplifying children's procedural knowledge or skills in copying, continuing or devising repeating patterns at 3½ and 4½ years was analysed. Following this, two statistical tests were performed to test the association between children's age and their copying, continuing and devising skills. Where conditions were met, with cell size of 5 or above, chi-square tests was performed. However, where expected cell values were less than 5, Fisher's exact test was used (Norusis 1993).

To investigate the second aspect of the first research question, qualitative data evidencing children's spatial pattern-making at 3½ and 4½ years was analysed. The two statistical tests detailed above were also used to test the association between children's age and their procedural knowledge in terms of spatial pattern-making.

The third aspect of the first research question was investigated through an analysis of qualitative data evidencing children's skills in co-ordinating colour organisation and spatial pattern-making. The two statistical tests detailed above were used to test the association between children's age and their skills in co-ordinating colour organisation and spatial pattern-making.

Finally, to investigate the fourth aspect of the first research question, an analysis was carried out on the qualitative data relating to children's knowledge and understanding about pattern at 3½ and 4½ years, in particular children's talk.

The Fifth Research Question

Turning to the fifth research question, tests were performed to assess the association between measures relating to two key aspects of children's pattern-making competencies, colour organisation and spatial organisation, and measures relating to other aspects of developing cognition. The test used to obtain measures of rank correlation between variables was Spearman's rho.

Additionally, in order to investigate gender related differences, box plots were used as an exploratory data analysis technique. Following this, in order to test the association between gender and children's competencies in the two strands of pattern-making, a measure of rank correlation, Spearman's rho, and its statistical significance for each pair of variables was obtained.

THE LONGITUDINAL STUDY

The longitudinal study provided data to support an examination of the three complementary research questions relating to the development of colour organisation and spatial organisation, two key aspects of young children's pattern-making knowledge, understanding and skills. These were the research questions, two, three and four:

2. Where do knowledge, understanding and skills in pattern-making begin and how do they develop between the ages of 3½ and 4½ years?
3. Are there individual differences in the detailed pathways taken towards knowledge, understanding and skills in pattern-making?
4. Are there individual differences in knowledge, understanding and skills in pattern-making and in rates of development between 3½ and 4½ years?

The Sample

The sample for the longitudinal study was selected from the nursery class as above. It comprised the twenty-four children from the cross-sectional study who were also included in the cross-sectional study sample at 4½ years. The initial sample of 25 children for the longitudinal study was reduced to 24 because one child left the school half way through the year of the study.

Pattern-related Assessment Activities

The pattern-making assessment activities for children at 3½ and 4½ years, as detailed above, provided data for the longitudinal study. In addition, a subset of the pattern-making assessment activities was repeated at two intermediate points in time in order to track children's development over the year. This subset comprised Bead Threading, Mosaic Tiles and Pegs and Pegboard. The Teddy's Beads assessment activities were excluded from the subset for two reasons. Firstly, Teddy's Beads was a relatively lengthy set of assessments and there were constraints on the teacher-researcher's time. Secondly, the novelty of the Teddy's Beads story scenario was planned as a motivating factor for the set of assessment activities. Additional repetitions of the assessments could have militated against children's enjoyment and therefore engagement in the activities. It was concluded that this might lead to an underestimation of competencies.

Observational Assessment Data

Observational assessment data relating to the 24 children in the longitudinal study were collected over the year of the study. Relevant data from the ongoing nursery profiling system were made available to the study. Members of the nursery staff were encouraged to record observed examples of spontaneous patterning play and pattern-making. The observational data included annotated photographs, drawings and descriptions of children's work. Where possible, relevant talk was also recorded.

Data Analysis

The development of children's procedural knowledge or skills in copying, continuing or devising repeating patterns

To investigate the first aspect of the research questions re-stated above, research questions 2, 3 and 4, qualitative data were analysed exemplifying the development of children's procedural knowledge or skills in copying, continuing or devising repeating patterns between 3½ and 4½ years. Following categorisation of the 24 children in the longitudinal study into high, medium and low groups in relation to work undertaken at 4½ years, a subset of eight children was selected to be presented as case studies for one or both strands of pattern-making. Case studies included two children from the high group for colour organisation, two children from the medium group and two children from the low group. One child exemplified a further interesting aspect of development within the colour organisation strand of pattern-making.

Following analysis of the case study data relating to colour organisation, a developmental pathway was hypothesised, leading from the earliest stage of identified development towards the highest identified stage of complex pattern-making. As part of the final stage of data analysis, an evaluation of the hypothesised pathway was undertaken using exploratory methods of data analysis. These were boxplots, a scatter diagram and a measure of correlation. Following this, a series of statistical tests was performed to evaluate the hypothesised pathway. Initially, the Wilcoxon test was performed on data from the longitudinal study. To support further evaluation of the hypothesised pathway, a second statistical test, the Mann Whitney U Test, was performed using data from the larger cross-sectional study.

The development of children's procedural knowledge or skills in spatial pattern-making

To investigate the second aspect of this set of research questions, research questions 2, 3 and 4, an analysis was carried out on the qualitative data exemplifying the development of children's procedural knowledge or skills in spatial patterning play and pattern-making between 3½ and 4½ years. Case study data were collected as above.

Following analysis of the case study data relating to spatial organisation, hypothesised developmental pathways were developed, taking account of data from the earliest stage of identified development towards the highest identified stages of complex spatial pattern-making. Hypothesised pathways were evaluated through the use of exploratory methods of data analysis and statistical tests, as above.

The development of children's knowledge and understanding about pattern

To investigate the final aspect of this set of research questions, qualitative data was analysed, exemplifying the development of children's knowledge and understanding about pattern between 3½ and 4½ years. Children's responses to the first Teddy's Beads assessment

activity and their pattern-related talk throughout the study were identified as the key data for analysis.

Following a review of the data from the 24 children in the longitudinal study, a subset of 8 children was selected as case studies. This subset included children from high, medium and low groups in terms of spatial organisation and colour organisation.

Towards the Presentation of Findings

The findings of the cross-sectional and longitudinal studies, as outlined in this chapter, are presented in Chapters 5, 6 and 7. These three chapters present findings in relation to each of the five main study research questions in turn. Chapter 5 focuses on the first research question, presenting findings relating to children's knowledge, understanding and skills in pattern-making at 3½ and 4½ years. Following this, Chapter 6 focuses on the second, third and fourth research questions, presenting findings relating to the development of children's knowledge, understanding and skills in pattern-making. Finally, Chapter 7 focuses on the fifth research question and presents findings relating to the ways that individual differences in children's knowledge, understanding and skills in pattern-making at 3½ and 4½ years are associated with differences across other dimensions of development. Following the presentation of findings, the implications of these findings for approaches to pattern in the foundation stage curriculum are considered in Chapter 8.

CHAPTER 5

PRESENTATION AND ANALYSIS OF RESULTS: KNOWLEDGE,

UNDERSTANDING AND SKILLS IN PATTERN-MAKING AT 3½ AND 4½ YEARS

INTRODUCTION

In this chapter, the first research question informing the main study is examined in the light of the qualitative and quantitative data yielded by the main study assessment activities. A presentation and analysis of first the qualitative and then the quantitative data shape the present chapter, as it relates to each aspect of the first research question:

1. What knowledge, understanding and skills in pattern-making do children demonstrate at 3½ and 4½ years of age?

The first aspect of pattern-making to be considered in examining this question is colour organisation, and in particular children's procedural knowledge or skills in copying, continuing and devising repeating patterns at 3½ and 4½ years of age. Analysis begins with a presentation of the qualitative data, exemplifying children's pattern-making skills at this age. Qualitative data are particularly important to the presentation and analysis of the more complex pattern-making undertaken by a small number of children at 4½ years. Following this, quantitative data relating to children's skills in this area are considered.

The second aspect of pattern-making to be considered in an examination of the first research question is spatial organisation. Data evidencing children's procedural knowledge or skills in devising linear and 2D symmetrical patterns are analysed. Analysis draws mainly on qualitative data from the Pegs and Pegboard assessment activity. The result of firstly, the open-ended nature of this activity and secondly, the wide-ranging nature of children's responses to the activity, was a data set of considerable complexity. Consequently, assessment data offers greater potential for qualitative than quantitative analysis. However, following analysis of the qualitative data, some quantitative data are presented.

The third aspect of pattern-making to be considered in addressing the research question above is children's procedural knowledge or skills in co-ordinating colour and spatial organisation. Again, analysis focuses on the complex qualitative data arising from children's work with pegs. Following this, however, some quantitative data are presented.

The final aspect to be considered, in addressing the research question above, is children's declarative knowledge and their understanding of pattern as a mathematical concept. Again the presentation of data has a main focus on qualitative data. Children's talk was recorded throughout the study and this data provides rich evidence relating to children's understandings in this area. There is also, however, a quantitative dimension to the presentation of results.

REPEATING PATTERNS: WHAT KNOWLEDGE, UNDERSTANDING AND SKILLS DO CHILDREN DEMONSTRATE AT 3½ AND 4½ YEARS OF AGE?

In the section that follows, qualitative and quantitative data, evidencing children's knowledge, understanding and skills in relation to the colour organisation strand of pattern-making are considered.

Qualitative and quantitative data provide evidence of children's comparative skills in copying, continuing and devising repeating patterns at 3½ and 4½ years. There is evidence relating to firstly, children's skills in copying, continuing and devising simple two unit repeating pattern and secondly, evidence relating to more complex repeating patterns. The data represent children's work with three different kinds of play materials, beads, pegs and mosaic tiles. Data are presented from four assessment contexts:

1. Bead Threading
2. Teddy's Beads
3. Mosaic Tiles
4. Pegs and Pegboard

REPEATING PATTERNS: QUALITATIVE DATA

Qualitative data relate mainly to children's knowledge, understanding and skills in relation to 2 unit repeating patterns at 3½ and 4½ years. All patterns modeled by adults during the study were 2 unit repeating patterns. Just two assessment activities, Teddy's Beads 4 and Pegs and Pegboard, were planned with a focus on children's skills in devising more complex repeating patterns.

Recording colour organisation

The recording system used in this chapter for the representation of colour organisation records the original colours of play materials in most cases. There are two exceptions. Firstly, white pegs are represented by purple. Secondly, grey is used to record the placement of coloured pegs where there is no supporting evidence of colour organisation.

Simple 2 unit repeating patterns

Devising a repeating pattern

At 3½ years, in the open-ended context of the Bead Threading activity, just two children were successful in devising a 2 unit repeating pattern in response to the invitation to make a pattern with beads. At 4½ years, 8.2% of children devised a 2 unit repeating pattern, as exemplified in Figure 5.1. No child, at either age, made a more complex repeating pattern while participating in this activity.

Active searching behaviour was observed as Christopher selected beads.

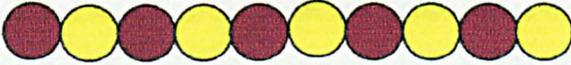
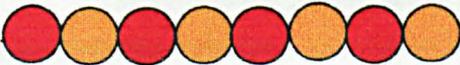


Figure 5.1 Bead Threading – Christopher’s pattern, devised in response to an invitation to make a pattern

The Teddy’s Beads 3 activity provided a second open-ended context, with children again invited to devise a pattern. At 3½ years no child was successful in devising a 2 unit repeating pattern in this context. At 4½ years, however, 10.6% of children were successful in devising a 2 unit repeating pattern, as exemplified in Figure 5.2

Active searching behaviour was observed as Rona selected beads.



“Red...I want red and orange.” (threading the first red bead)

Figure 5.2 Teddy’s Beads 3 – Rona’s devised repeating pattern

The Mosaic Tiles 1 activity offered a third open-ended context with children invited to devise a pattern. At 3½ years no child was successful in devising a repeating pattern. At 4½ years, 18.4% of children were successful in devising a 2 unit repeating pattern, as exemplified in Figure 5.3. One child devised a more complex repeating pattern, a repeating sequence of five colours.

Active searching behaviour was observed as Gemma selected beads.



Figure 5.3 Mosaic Tiles 1 – Gemma’s devised repeating pattern

The Mosaic Tiles 2 activity offered a fourth open-ended context where children were invited to devise a pattern, this time following adult modeling of repeated pattern-making. At 3½ years, 18% of children made repeating patterns. Most children copied the modeled colours. Just two of the group devised a 2 unit repeating pattern, using self-selected colours. At 4½

years, 36.7% of children made 2 unit repeating patterns but again the majority of children copied the modeled colours. Six of the children, however, devised a 2 unit pattern using a self-selected colour combination, as exemplified in Figure 5.4. At 4½ years, three further children devised more complex repeating patterns, making their patterns with 3 or 4 units. One of the 4 unit repeating patterns is illustrated in Figure 5.9 below.

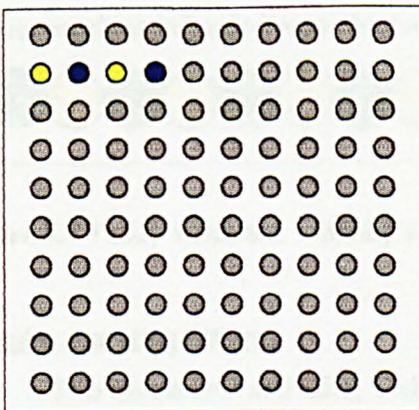
Active searching behaviour was observed as Gemma selected beads.



“Red.” (placing the first tile)

Figure 5.4 Mosaic Tiles 2 – Gemma’s devised pattern, following modeled repeated pattern-making

The Pegs and pegboard activity presented the fifth and final open-ended context for repeated pattern-making. At 3½ years, one child evidenced perception of a devised 2 unit repeating pattern illustrated in Figure 5.5.



Rachel said, “Look blue, yellow, blue, yellow,” following placement of the indicated pegs. There was, however, no evidence that Rachel intended to devise this sequence.

Figure 5.5 Rachel’s devised peg pattern

At 4½ years, one child was successful in devising a 2 unit repeating pattern in the Pegs and Pegboard activity. A further child devised a repeated difference series, a repeated sequence of five colours. In addition, 6.3% of children devised more complex repeating patterns. This work is exemplified and discussed below in the section relating to complex repeating patterns.

Copying a repeating pattern

The Teddy's Beads 1 activity provided a context for copying 2 unit repeating patterns. At 3½ years, 4.6% of children were successful in copying a 2 unit repeating pattern. At 4½ years, 32.7% of children were successful, as exemplified in Figure 5.6.

Active searching behaviour was observed as Gemma selected beads. Once she had started threading, Gemma did not look back to the model pattern.

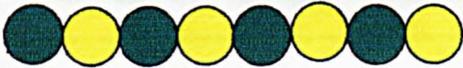


Figure 5.6 Teddy's Beads 1 – Gemma's copied 2 unit repeating pattern

Continuing a repeating pattern

The Teddy's Beads 2 activity provided a context for continuing a 2 unit repeating pattern. At 3½ years, one child was successful in continuing a 2 unit repeating pattern. At 4½ years, 27.6% of children were successful, as exemplified in Figure 5.7 below.

Active searching behaviour was observed as Bobby selected beads.

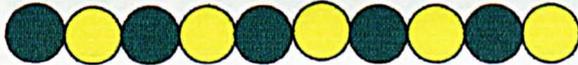


Figure 5.7 Teddy's Beads 2 – Bobby's continued 2 unit repeating pattern

Complex repeating patterns

Two assessment activities, Teddy's Beads 4 and Pegs and Pegboard, focused on children's skills in devising more complex repeating patterns. Main study data relating to the sample at 4½ years, but not at 3½ years, evidences a small group of children with skills in devising repeating patterns more complex than those exemplified above. These more complex patterns were of two kinds. Firstly, a small group of children devised repeating patterns with 3 or more units. Repeating patterns with three or more units were devised mainly but not only in the Teddy's Beads 4 activity. Secondly, a smaller group of children devised sequences of repeating patterns in work with pegs, sustained across the lines of the pegboard.

Examples of this more complex work are presented and discussed below. Firstly, work comprising repeating patterns with 3 or more units is considered. Secondly, work comprising sustained sequences of repeating patterns is considered.

3 + unit repeating patterns

At 4½ years, in the Teddy's Beads 4 activity, 9.8% of children were successful in responding to the invitation to make a pattern with three colours, red, green and yellow. These children made 3 unit repeating patterns, as exemplified in Figure 5.8 below.

Active searching behaviour was observed as Karla selected beads.

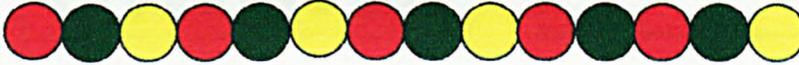


Figure 5.8 Teddy's Beads 4 – Karla's devised pattern with 3 specified colours

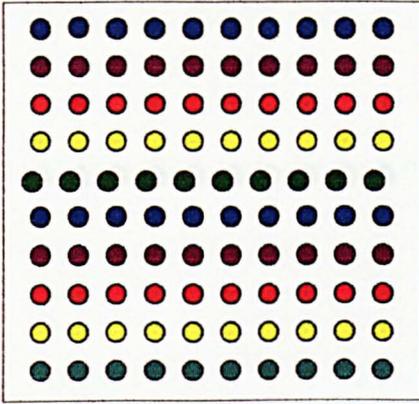
In the Mosaic Tiles 1 activity, one child devised a five unit repeating pattern. Similarly, in the Mosaic Tiles 2 activity, one child devised a 3 unit repeating pattern and two children devised 4 unit repeating patterns. Matthew's 4 unit sequence is illustrated in Figure 5.9.

Before starting to work, Matthew said, "I'll show you my pattern." He then said colour names as he placed the tiles for a 4 unit repeating pattern



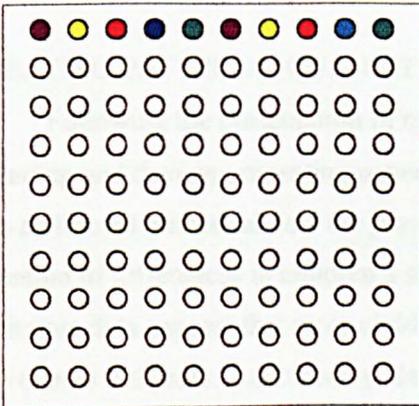
Figure 5.9 Mosaic Tiles 2 – Matthew's devised pattern, following adult modeling

In the Pegs and Pegboard activity at 3½ years, the same child, Matthew, devised a 2D repeating sequence, illustrated in Figure 5.10. One child devised a 5 unit repeated sequence, illustrated in Figure 5.11.



In Matthew's work with pegs, illustrated in Figure 5.10, each line of pegs functions as a unit (a line-unit). There is one repeat of the 5 unit sequence.

Figure 5.10 Matthew's devised peg pattern

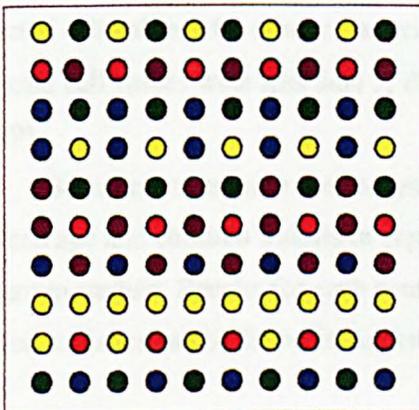


In work with pegs at 4½ years, Karla devised a repeated difference series, a linear repeating sequence of five colours.

Table 5.11 Karla's devised peg pattern

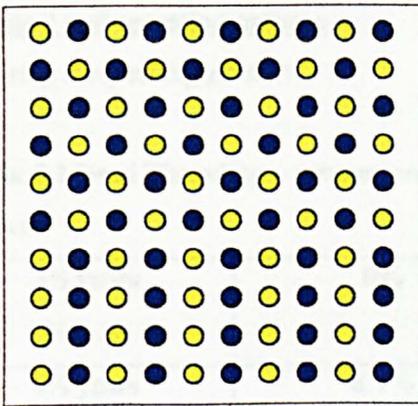
Sequences of Repeating Patterns

At 4½ years, in work with pegs, two children devised sequences of repeating patterns, sustained across the lines of the pegboard.



As illustrated in Figures 5.12 and 5.13, Rona and Nicole both devised patterns based on the use of alternating line-units. A line unit is defined as a 2 unit repeating pattern sustained across a pegboard line. Rona, as illustrated in Figure 5.12, devised a sequence of seven contrasting alternating line-units with two line-units repeated.

Figure 5.12 Rona's devised peg pattern



Nicole devised a complex 2D pattern. As illustrated in Figure 5.13, an initial alternating line-unit is reversed in the second line. This two-line sequence is then repeated twice. Following this, the first line is repeated four times.

Figure 5.13 Nicole's devised peg pattern

REPEATING PATTERNS: QUANTITATIVE DATA

Following the presentation of qualitative data relating to children's skills in copying, continuing and devising repeating patterns, in the section that follows quantitative data and some additional numerical data are presented. The quantitative analysis is important to the evaluation of differences in children's skills in repeated pattern-making at 3½ and 4½ years. Qualitative data suggest that more children copy, continue and devise repeating patterns at 4½ years than at 3½ years. Additionally, data suggest that a small group of children at 4½ years have more advanced pattern-making skills than the skills evidenced by children at 3½ years. Quantitative analysis allows for the further examination of these findings.

In the section that follows, the analysis of numerical data discriminates between early levels of skill, where a sequence is repeated just once or twice, and secure skills, where children sustain pattern-making with 3+ repeats.

To test the association between age and children's skills in copying, continuing and devising repeating patterns, two statistical tests were used. Where conditions were met, with expected cell values of 5 or more, a series of chi-square tests were performed. Where the expected cell values were less than 5, Fisher's exact test was used, as outlined by Norusis (1993, p. 209).

Statistical tests were used to test the null hypothesis that there is no relationship between age and children's skills in copying, continuing or devising repeating patterns in the age group studied. Results for each context are reported in the tables below. Examples of worked statistics can be found in Appendix 3.

Simple 2 unit repeating patterns*Devising a repeating pattern***Table 5.1** Bead Threading – proportional success when devising a simple 2 unit repeating pattern

3½ years N = 50	0%	0%	sustained
		0%	not sustained
4½ years N = 49	8.1%	2%	sustained
		6.1%	not sustained

Fisher's exact test carried out on the data provides a one-tailed p value of .056, just outside the conventionally accepted .05 level. Therefore the null hypothesis can not be rejected at the .05 level. For the age group studied, the statistics suggest an association between children's age and their skills in devising repeating patterns with beads that is just less than convincing.

Table 5.2 Teddy's Beads 3 - proportional success when devising a repeating pattern

3½ years N = 43	0%	0%	sustained
		0%	not sustained
4½ years N = 48	14.3%	6.1%	sustained
		8.2%	not sustained

Fisher's exact test carried out on the data provides a one-tailed p value of .006. Therefore the null hypothesis can be rejected at a .01 level of probability. The statistics suggest, for the age group studied a significant association between children's age and their skills in devising simple 2 unit repeating patterns.

Table 5.3 Mosaic Tiles 1 - proportional success when devising a simple 2 unit repeating pattern

3½ years N = 50	0%	0%	sustained
		0%	not sustained
4½ years N = 49	20.4%	16.3%	sustained
		4.1%	not sustained

Fisher's exact test carried out on the data provides a one-tailed p value of .001. Therefore the null hypothesis can be rejected at a .001 level of probability. The statistics suggest, for the age group studied a significant association between children's age and their skills in devising repeating patterns in work with mosaic tiles.

Table 5.4 Mosaic Tiles 2 – proportional success when making a simple 2 unit repeating pattern following modeled pattern-making

3½ years N = 50	18%	14%	model colours - sustained
		0%	self-selected colours - sustained
		2%	model colours - not sustained
		2%	self-selected colours – not sustained
4½ years N = 49	36.7%	18.4%	model colours - sustained
		12.2%	self-selected colours - sustained
		4.1%	model colours - not sustained
		2%	self-selected colours - not sustained
<p>The value of χ^2 obtained (8.37923) when $df = 1$ is significant at the 0.036 level of probability. Therefore the null hypothesis can be rejected at a .05 level of probability. The statistics suggest a significant association, for the age group studied, between age and children's skills in making a repeating pattern in work with mosaic tiles, following modeled pattern-making.</p>			

Copying a repeating pattern

Table 5.5 Teddy's Beads 1 - proportional success when copying a simple 2 unit repeating pattern

3½ years N = 49	6.1%	2%	sustained
		4.1%	not sustained
4½ years N = 49	36.7%	22.4%	sustained
		14.3%	not sustained
<p>The value of χ^2 obtained (11.87879) when $df = 1$ is significant at the 0.001 level of probability. Therefore the null hypothesis can be rejected. The statistics suggest a significant association, for the age group studied, between age and children's skills in copying simple 2 unit repeating patterns in work with beads.</p>			

*Continuing a repeating pattern***Table 5.6** Teddy's Beads 2 - proportional success when continuing a simple 2 unit repeating pattern

3½ years N = 49	2%	0%	sustained
		2%	not sustained
4½ years N = 49	32.6%	26.5%	sustained
		6.1%	not sustained

The value of χ^2 obtained (13.94916) when $df = 1$ is significant at the 0.001 level of probability. Therefore the null hypothesis can be rejected. The statistics suggest a significant association between age and children's skills in continuing a simple 2 unit repeating pattern in work with beads.

Complex repeating patterns*3 + unit repeating patterns***Table 5.7** Teddy's Beads 4 - proportional success when devising a repeating pattern with 3 specified colours

3½ years	0%	0%	sustained
		0%	not sustained
4½ years	14.3%	10.2%	sustained
		4.1%	not sustained

Fisher's exact test carried out on the data provides a one-tailed p value of .006. Therefore the null hypothesis can be rejected at a .01 level of probability. The statistics suggest a significant association between children's age and their skills in devising a repeating pattern with 3 specified colours.

At 4½ years, one child did not respond to the activity as anticipated and instead devised a 2 unit repeating pattern.

Repeating Patterns in Pegs and Pegboard work

Very small numbers of children devised repeating patterns in work with pegs. Simple and complex work has been combined in the following table of results.

Table 5.8 Pegs and Pegboard – proportional success when devising sequences of repeating patterns

3½ years N = 50	2%	0%	sustained
		2%	not sustained
4½ years N = 48	8.4%	6.3%	sustained
		2.1%	not sustained
Fisher's exact test carried out on the data provides a one-tailed p value of .168. Therefore the null hypothesis is not rejected. The statistics do not provide evidence of a convincing association between children's age and their skills in devising repeating patterns in work with pegs in the age group studied.			

REPEATING PATTERNS: SUMMARY

3½ years

At 3½ years, a small group of children evidenced skills in copying and continuing 2 unit repeating patterns. At this age, however, very few children devised repeating patterns of their own. Of those children who copied and continued repeating patterns in work with beads, very few worked in a sustained way. However, in work with tiles, following modeled pattern-making, and where an adult had verbalized the colour sequence, a significant minority of children sustained their repeated sequences. At 3½ years, just one child evidenced skills in devising more complex repeating patterns with sequences of 3+ units.

In summary, there is evidence of early pattern-making skills for a small group of children who copied and continued simple repeating patterns in one or two specific contexts. However, at 3½ years, no children demonstrated secure or flexible skills and procedural knowledge by copying, continuing and devising repeating patterns across a range of contexts.

4½ years

At 4½ years, a continuing majority group of children evidenced no skills in copying or continuing simple repeating patterns. However, the statistical analysis does demonstrate a significant association between the age of children and their skills in copying, continuing or devising repeating patterns for six out of eight assessment contexts.

Significant development can be seen in the fact that, by 4½ years, a significant minority, approximately one third of children, demonstrated skills in copying or continuing 2 unit repeating patterns. A majority of this group demonstrated relatively secure levels of skill, sustaining a repeating pattern through three or more repeats.

In contrast to children at 3½ years, a small group of children also evidenced skills additional to those of copying and continuing patterns. These children devised their own repeating patterns. At 4½ years, about one fifth of children choose to devise a pattern rather than

copy an adult's pattern following adult modeling of repeated pattern-making with tiles.

However, this group of children remained smaller than the group that was successful in copying and continuing patterns.

At 4½ years a small group of children also demonstrated skills in working with more complex repeating patterns. These more complex patterns were of two kinds. Firstly, a small group of children devised repeating patterns with 3 or more elements. Secondly, in work with pegs, a very small group devised sequences of repeated patterns, sustained across the lines of the pegboard.

At 4½ years, a significant minority of children demonstrated secure and flexible skills and procedural knowledge, copying, continuing and devising repeating patterns across a range of contexts. However, for most of the children, the skills and procedural knowledge evidenced were less secure and less flexible. This larger group copied and continued simple repeating patterns, but in only one or two contexts.

SPATIAL PATTERNS: WHAT KNOWLEDGE, UNDERSTANDING AND SKILLS DO CHILDREN DEMONSTRATE AT 3½ AND 4½ YEARS OF AGE?

In the section that follows, complex qualitative data evidencing children's knowledge, understanding and skills in relation to the spatial organisation strand of pattern-making are considered. This is followed by a quantitative analysis of some aspects of the data. Qualitative and quantitative data both provide evidence of children's skills in devising linear and 2D symmetrical patterns at 3½ and 4½ years of age.

No models of linear or 2D symmetrical patterns were provided during the main study assessment activities focused on spatial organisation. The Pegs and Pegboard assessment activity was designed to elicit children's devised rather than copied work in the spatial organisation strand of pattern-making. This contrasts with the assessment activities focused on repeating patterns. The only spatial modeling provided was modeling of the unidirectional proximity placement of tiles in the Mosaic Tiles assessment activity.

SPATIAL PATTERNS: QUALITATIVE DATA

Linear and 2D Symmetrical Patterns

The spontaneous use of linear symmetrical markings was not a feature of children's work with mosaic tiles or pegs in this study. Just one child, Dylan, marked a pegboard line with symmetrical markings at 4½ years and, in this case, the linear symmetry was a single aspect of a more complex 2D pattern. The use of symmetrical markings in Dylan's work is discussed in the section relating to children's co-ordination of spatial and colour organisation.

There was, however, a range of evidence relating to children's spontaneous use of symmetrical patterning in 2D work with pegs. This section focuses on data from the 2D pattern-making assessment activity, Pegs and Pegboard. In this activity, although no models of pattern were presented to children for imitation, a small group of children at 3½ years and approximately one quarter of children at 4½ years were successful in devising their own 2D symmetrical patterns. In this section, the skills and procedural knowledge of this small group who devised 2D spatial patterns is examined more closely through the presentation and analysis of the patterns they made.

Spatial Patterns at 3½ Years

The examples that follow are the three 2D symmetrical patterns devised by children at 3½ years. 2D symmetrical patterns are defined in this study as incorporating at least two basic elements of pattern or complex forms of linear organisation, as defined in Appendix 4. In the patterns illustrated below, children made use of the following basic elements of pattern and elements of complex linear organisation, as exemplified in Appendix 4:

- non-linear basic elements
 - marking the centre – sustained
 - enclosing the centre - sustained
 - marking the corners – sustained
 - marking two midpoints
- complex linear organisation
 - rectangle

Recording categories of spatial organisation

Some children, having made a symmetrical pattern with pegs, went on to place further pegs on the pegboard, often continuing until they had filled the whole pegboard. In most of the examples presented below, these additional pegs have not been recorded. The exceptions to this are those cases where the child's work included elements of pattern additional to those exemplified in the criteria for symmetrical patterns.

The following recording system is used to support identification of the pattern elements in children's work illustrated below:

- The nonlinear basic elements, marking the centre, marking the corners and marking two mid-points, are recorded in black.
- The nonlinear basic element enclosing the centre is recorded in grey.
- The connected basic elements are recorded in grey.
- The order of placement of elements of pattern is described but not recorded.

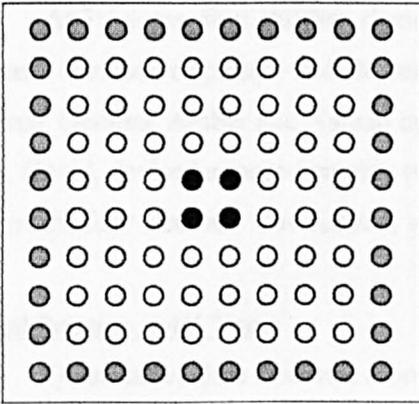


Figure 5.14 Gemma's and Amber's devised peg pattern

Gemma, as seen in Figure 5.14, began by placing pegs to make a 'rectangle.' She then placed pegs for 'marking the centre,' before going on to fill the pegboard. She used no additional elements of pattern.

Amber made a similar pattern, with a similar placement order. She also went on to fill the pegboard but with no further use of identified elements of pattern.

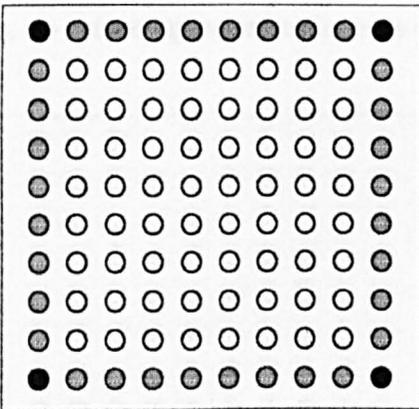


Figure 5.15 Nathan's devised peg pattern

In this pattern, Figure 5.15, Nathan began by placing pegs for 'marking the corners'. He then placed pegs to complete the 'rectangle.' Nathan went on to fill the pegboard, mainly through the placement of horizontal lines. However, he made no further use of identified elements of pattern.

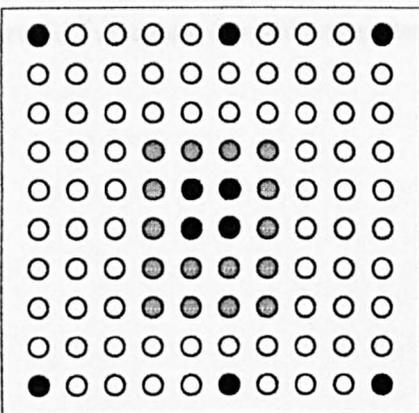


Figure 5.16 David's devised peg pattern

David, in Figure 5.16 began by placing pegs for 'marking the centre'. He then placed pegs for 'enclosing the centre'. Pegs were placed symmetrically to enclose the centre, with two pegs placed to the right of the centre, followed by two pegs to the left. David then placed four pegs above the marked centre, followed by four pegs below it.

An additional line was placed beneath this. David went on to place four pegs for 'marking the corners'. Finally, he placed pegs for 'marking two midpoints'.

At 3½ years, four children devised symmetrical patterns through the coordinated use of the basic elements of pattern and elements of complex linear organisation listed above. Three children, Gemma, Amber and Nathan devised patterns incorporating two elements. The fourth child, David, devised a more complex pattern, incorporating four elements. In David's pattern, each of the four elements was distinct, with no elements repeated.

Spatial Patterns at 4½ Years

Quantitative data evidence more children at 4½ years than 3½ years using pegs to make symmetrical 2D patterns. Children at 4½ years also devised a wider range of patterns than devised by children at 3½ years. Many children at 4½ years made use of the same elements of pattern as children at 3½ years and they used these elements in similar ways.

The examples below represent those symmetrical patterns devised by children at 4½ years, co-ordinating the same elements of pattern as used by children at 3½ years

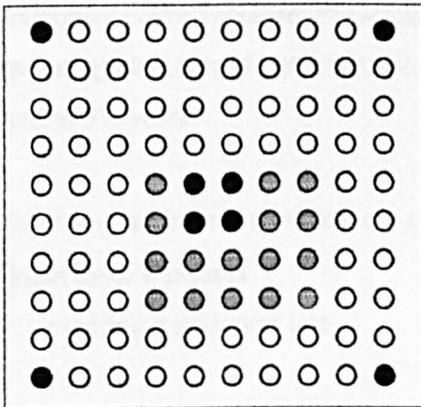


Figure 5.17 Joanne's devised peg pattern

In Figure 5.17, Joanne began by placing pegs for 'marking the centre'. She then placed pegs around three sides of the marked centre. Following this, she placed further pegs around two of the sides. Finally, Joanne placed pegs for 'marking the corners.'

Joanne's completed pattern was similar to David's pattern above, but it incorporated just two elements of pattern. There were further similarities in placement order.

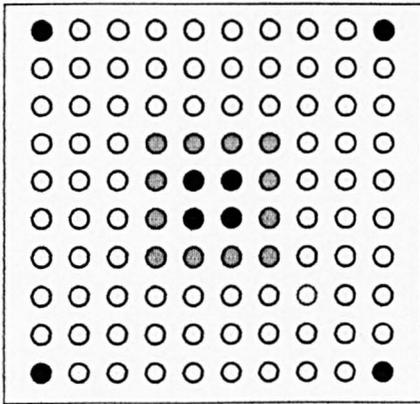


Figure 5.18 Amy's devised peg pattern

Amy, in Figure 5.18, began by placing four pegs for 'marking the corners' and then placed pegs for 'marking the centre'. Following this, she went on to place pegs for 'enclosing the centre'. Amy continued to place pegs, filling half the pegboard but with no further use of elements of pattern.

Amy's pattern was similar to those of Joanne and David but with a different placement order. All three children marked the centre and then went on to elaborate this centre

The examples below represent the symmetrical patterns devised by children at 4½ years, incorporating elements of pattern and complex linear organisation additional to those used by children at 3½ years.

The following additional elements are exemplified in Appendix 4.

- linear basic elements
 - marking a midpoint line
- elements of complex linear organisation
 - marking a diagonal line
 - marking 8 parallel horizontal/vertical lines - unidirectional proximity placing – sustained
 - marking 10 parallel horizontal/vertical lines - unidirectional proximity placing – sustained

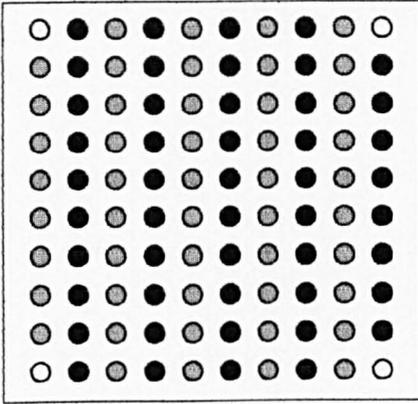
Recording categories of spatial organisation

The recording system detailed above is used to support identification of the patterned elements in children's work. In some cases, however, the following modification has been made to the colouring to aid identification of patterned elements:

- Basic elements of pattern are coloured in white, instead of black.

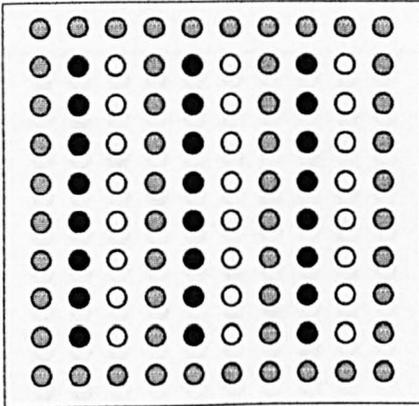
There are additional markings for new elements of symmetry:

- Black and grey or black, grey and white colouring is used to highlight parallel lines
- Single lines are marked in grey or black.



In this pattern, Figure 5.19, Charlotte began by placing four pegs for 'marking the corners'. She then went on to fill the pegboard, marking '10 parallel vertical lines' with sustained unidirectional proximity placement.

Figure 5.19 Charlotte's devised peg pattern



Two children made this pattern, Figure 5.20. Emma and Lisa both began by placing pegs to make a 'rectangle.' They both went on to fill their pegboards, marking '8 parallel vertical lines' with sustained unidirectional proximity placement.

Figure 5.20 Emma's and Lisa's devised peg pattern

Laura made a similar pattern with a similar placement order but filled the pegboard using 'parallel horizontal lines'

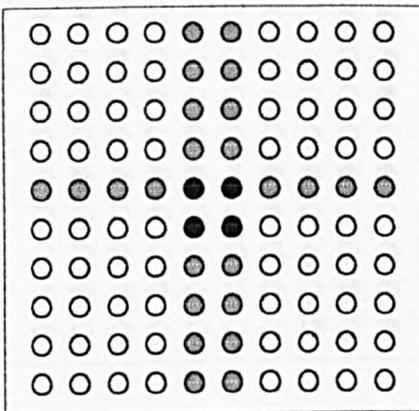


Figure 5.21 Jame's devised peg pattern

James, in Figure 5.21, began by placing pegs for 'marking the centre.' He then placed pegs to make two lines below the marked centre. Following this, he placed the additional pegs necessary for 'marking a midpoint line,' Finally, James placed two pegs to make two lines above the marked centre.

Although placement order was not followed, James achieved the repeated effect of 'marking a midpoint line' with two lines made above and below the marked centre.

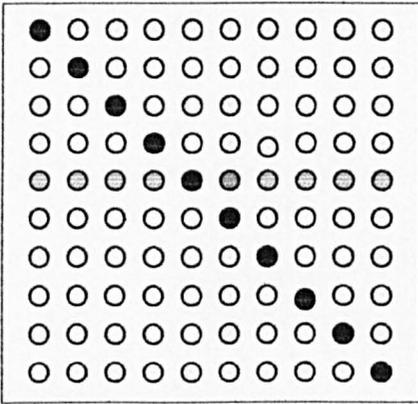


Figure 5.22 Matthew's devised peg pattern

Matthew, in Figure 5.22, began by placing pegs for 'marking a diagonal line'. He then went on to place pegs for 'marking a midpoint line'.

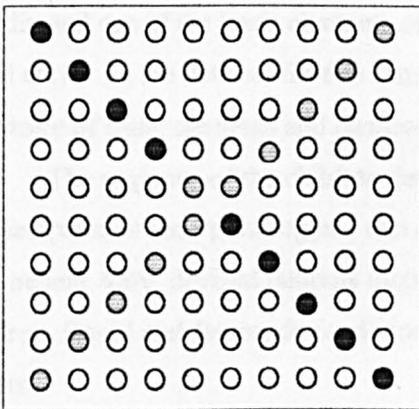


Figure 5.23 Joseph's devised peg pattern

In this pattern, Figure 5.23, Joseph began by placing pegs for 'marking a diagonal line' but with the fifth hole left empty. He then went on to place pegs for the intersecting diagonal line, filling the empty hole as a part of this sequence.

Josh made the same spatial pattern but with a different placement order. Each diagonal line was made with the unidirectional proximity placement of pegs.

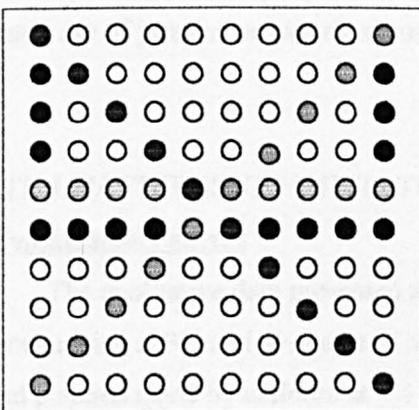
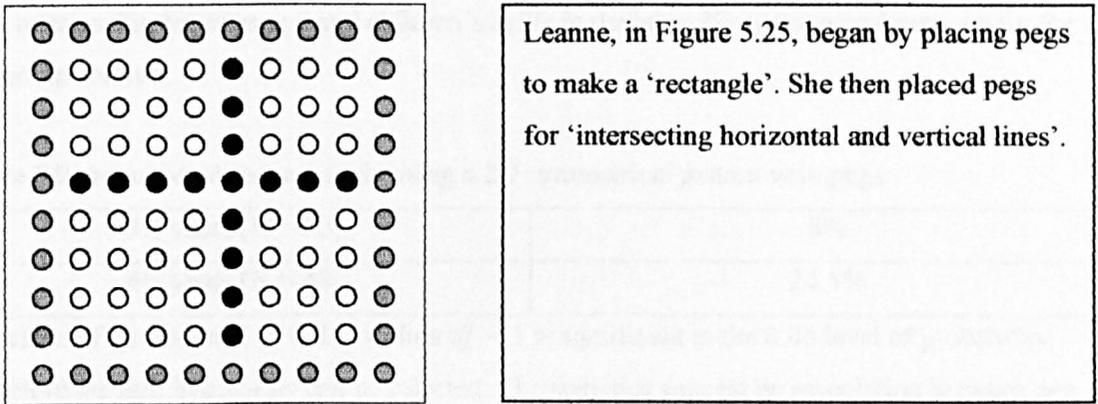


Figure 5.24 Dylan's devised peg pattern

In making the pattern, Figure 5.24, Dylan first placed pegs for 'intersecting diagonal lines.' He then placed pegs to complete 'marking a midpoint line,' marking the line through the symmetrical placement of pegs. Dylan then placed a second line of pegs to repeat 'marking a midpoint line.' He again placed pegs symmetrically along the line but with a different placement order.

Following this, Dylan placed three pegs in a line on each side of the upper half of his pegboard. In filling the pegboard, Dylan used no further elements of pattern.



Leanne, in Figure 5.25, began by placing pegs to make a 'rectangle'. She then placed pegs for 'intersecting horizontal and vertical lines'.

Figure 5.25 Leanne's devised peg pattern

At 4½ years, twelve children devised a wide range of symmetrical patterns through the coordinated use of the basic elements of pattern and elements of complex linear organisation listed above. In the data set for this sample, three new linear elements were additional to the repertoire of basic elements and elements of complex linear organisation observed at 3½ years.

The majority of the children devising symmetrical patterns at 4½ years, eight children, devised patterns incorporating just two elements of pattern as at 3½ years. Just two children, Leanne and Amy, devised patterns incorporating three elements of pattern. A further two children, David and James, devised more complex patterns, incorporating four elements of pattern.

At 4½ years, no other child used as many different elements of pattern as the four distinct elements used by David at 3½ years. At 4½ years, Amy used the highest number of different elements of pattern and she used just three. Four children, Leanne, Dylan, Joseph and James, made relatively complex symmetrical patterns, but this was a consequence of their repeated use of just one or two elements of pattern.

SPATIAL PATTERNS: QUANTITATIVE DATA

2D Symmetrical Patterns

The qualitative data presented above provide evidence of children's skills in spatial pattern-making at 3½ and 4½ years of age. The qualitative data demonstrate the greater range of spatial patterns made by children at 4½ years than at 3½ years, with some of the patterns of the older children incorporating new spatial elements.

In the section that follows, quantitative data are considered. The quantitative analysis contributes to the evaluation of differences in children's skills in spatial pattern-making at 3½ and 4½ years.

To test the association between age and children's skills in devising 2D symmetrical patterns, as defined above, a chi-square test was performed. The null hypothesis states that there

is no relationship between age and children's skills in devising 2D symmetrical patterns for the age group studied.

Table 5.9 proportional success in devising a 2D symmetrical pattern with pegs

3½ years (N = 50)	8%
4½ years (N = 48)	24.5%
The value of χ^2 obtained (4.01116) when $df = 1$ is significant at the 0.05 level of probability. Therefore the null hypothesis can be rejected. The statistics suggest an association between age and children's skills in devising 2D symmetrical patterns in work with pegs for the age group studied.	

SPATIAL PATTERNS: SUMMARY

3½ years

No children at 3½ years evidenced skills in using tiles or pegs to mark a line symmetrically. However, four children evidenced skills in 2D spatial patterning in their work with pegs. The pegboard work illustrated above shows how this small group of children, at 3½ years, creatively combined two or more of five basic elements of patterns. Three of the four patterns devised combined a rectangle with a non-linear basic element. The fourth combined non-linear elements only. This, however, was a more complex pattern, incorporating four basic elements of pattern.

4½ years

At 4½ years, just one child evidenced skills in marking a line symmetrically in work with pegs. In addition, a significant minority, contrasting with the very small group at 3½ years, evidenced skills in 2D spatial patterning. These children creatively combined two or more basic elements of pattern. The statistical analysis of data suggests a significant association between children's skills in 2D spatial patterning and age for the age groups studied.

Some children at 4½ years made use of the same basic elements of pattern as used by children at 3½ years. A greater number of children made use of new linear and/or repeated basic elements. At 4½ years children made increased use of linear organisation, drawing on a widened repertoire of linear basic elements. Additionally, they made increased use of repeated elements. As a result, children at 4½ years devised a significantly wider range of spatial patterns than children at 3½ years.

**CO-ORDINATED COLOUR ORGANISATION AND SPATIAL PATTERN-MAKING:
WHAT KNOWLEDGE, UNDERSTANDING AND SKILLS DO CHILDREN
DEMONSTRATE AT 3½ AND 4½ YEARS OF AGE?**

Colour organisation and spatial organisation are two distinct strands within early pattern-making. Two main study assessment contexts, Bead Threading and Teddy's Beads focused on colour organisation alone. The 2D pattern-making assessment activity, using pegs, provided the key context for an examination of young children's skills in coordinating these two strands. In the section that follows, qualitative and quantitative data, evidencing children's knowledge, understanding and skills in relation to the co-ordination of colour organisation and spatial patterning are considered.

**CO-ORDINATED COLOUR ORGANISATION AND SPATIAL PATTERN-MAKING:
QUALITATIVE DATA**

The work detailed below illustrates the ways that children co-ordinated colour organisation and spatial organisation at 3½ and 4½ years.

Recording categories of colour and spatial organisation

The recording system used to date is used in this section, with white, black and grey representing aspects of spatial organisation. In addition, where children used colour organisation as a part of their pattern-making, the recording system makes use of additional colours. In these contexts, the recording system matches the original colours of selected play materials but with one exception. Purple is used for the representation of white pegs.

3½ years - co-ordinating colour and spatial organisation

At 3½ years, a very small group of children devised 2D symmetrical patterns. From this group, just one child demonstrated skills in coordinating colour organisation with spatial pattern-making.

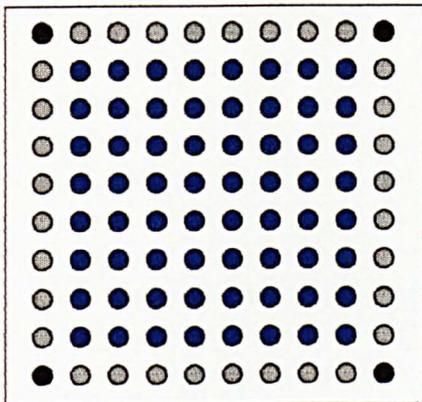


Figure 5.26 Nathan's devised peg pattern (colour and spatial organisation)

Nathan, in Figure 5.26, co-ordinated colour organisation and a 2D symmetrical pattern. He first marked the corners and then marked four connected lines to complete a 'rectangle'. This initial spatial patterning was undertaken without concern for colour organisation.

Following this, Nathan went on to fill the central area of the pegboard using blue pegs. He began this part of his pattern by marking 6 parallel horizontal lines.

4½ years - co-ordinating colour organisation and linear symmetrical markings

The coordination of colour and symmetrical linear patterning was first observed at 4½ years but in the work of just one child, Dylan. Dylan co-ordinated colour organisation and linear symmetrical markings as one part of a 2D symmetrical pattern, presented in Figure 5.24 above. His use of coordinated colour organisation and linear symmetrical markings as an additional feature of this pattern is highlighted below in Figure 5.27.

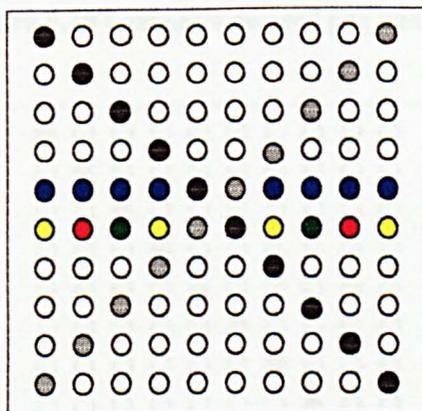
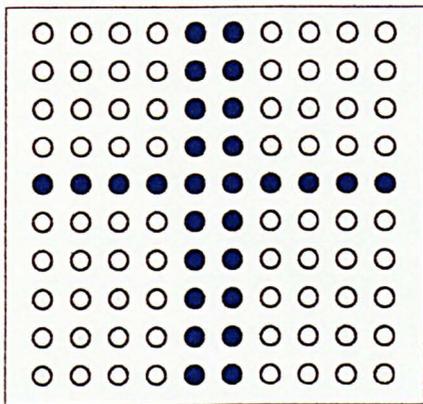


Figure 5.27 Dylan's devised peg pattern (colour and spatial organisation)

Dylan, in Figure 5.27, coordinated colour and spatial symmetry in the symmetrical marking of the lower midpoint line. He then coordinated colour organisation, selecting a set of blue pegs for symmetrical marking of the upper midpoint line.

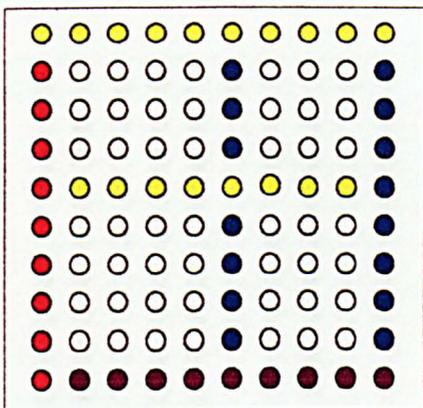
4½ years – co-ordinating colour organisation and 2D symmetrical pattern-making

The work of the larger group of children who devised 2D symmetrical patterns at 4½ years has been reviewed above. A small group of these children, in addition to Dylan, made co-ordinated use of colour organisation in their patterns at 4½ years. The work of these children, as 2D symmetrical patterns, has been presented above (Figures 5.20, 5.21, 5.22, 5.23 and 5.25). The use of colour organisation, as an additional feature of these children's 2D patterns, is highlighted below.



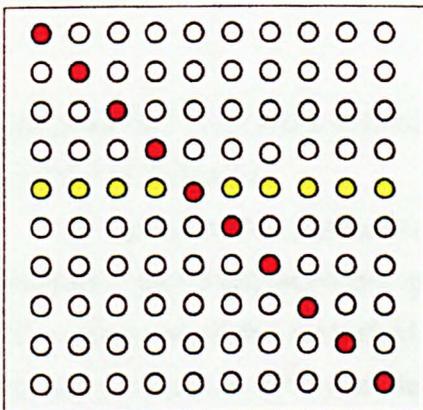
As illustrated in Figure 5.28, James co-ordinated colour organisation, evidenced in the sustained selection of blue pegs, with spatial organisation, evidenced in the symmetrical design of the work.

Figure 5.28 Jame’s devised peg pattern (colour and spatial organisation)



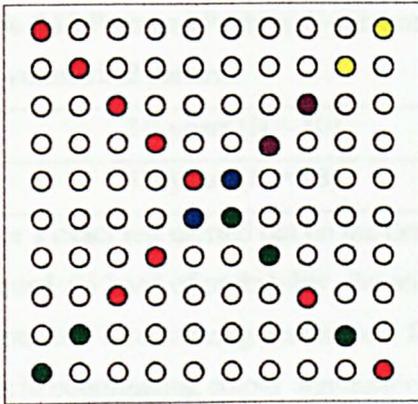
In this pattern, Figure 5.29, Leanne co-ordinated colour organisation, in the sustained selection of contrasting colours for lines of pegs, with the devising of a 2D symmetrical pattern.

Figure 5.29 Leannes’s devised peg pattern (colour and spatial organisation)



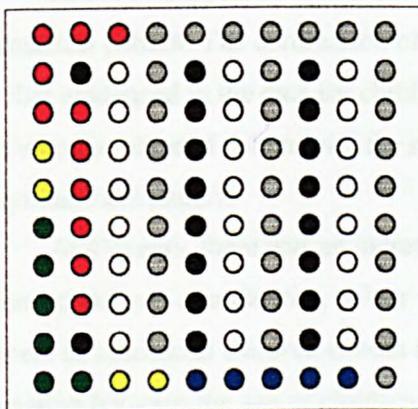
Matthew, as seen in Figure 5.30, co-ordinated colour organisation, in the sustained selection of contrasting colours for two lines of pegs, with devising a 2D symmetrical pattern.

Figure 5.30 Matthew’s devised peg pattern (colour and spatial organisation)



In this pattern, Figure 5.31, Josh co-ordinated colour organisation, in the sustained chaining of pairs of same colour pegs, with placement of the first diagonal line. He then co-ordinated colour organisation, in the alternation of sets of pegs, with placement of the second intersecting diagonal line.

Figure 5.31 Josh's devised peg pattern (colour and spatial organisation)



Emma, in Figure 5.32, co-ordinated colour organisation, evident in the chaining of sets of pegs, with spatial organisation. The spatial pattern comprised 'marking 8 parallel vertical lines,' enclosed within a 'rectangle'.

Figure 5.32 Emma's devised peg pattern (colour and spatial organisation)

CO-ORDINATED COLOUR ORGANISATION AND SPATIAL PATTERN-MAKING: QUANTITATIVE DATA

The qualitative data presented above provide evidence of children's skills in coordinating colour organisation and spatial pattern-making at 3½ and 4½ years of age. The qualitative data suggest that more children coordinated colour organisation and spatial pattern-making at 4½ years than at 3½ years and that they did this in more varied ways.

In the section that follows, quantitative data are considered. The quantitative analysis contributes to the evaluation of differences in children's skills in co-ordinating colour organisation and spatial pattern-making at 3½ and 4½ years.

To test the association between age and children's skills in coordinating colour organisation and spatial pattern-making, a chi-square test was performed. The null hypothesis states that there is no relationship between age, for children at 3½ and 4½ years, and children's skills in coordinating colour organisation and spatial pattern-making.

Table 5.10 Pegs and Pegboard – proportional success in coordinating colour organisation and 2D symmetrical patterns

3½ years (N = 50)	2%
4½ years (N = 48)	10.42%
Fisher's exact test carried out on the data provides a one-tailed p value of .098. Therefore, at the accepted .05 level of probability, the null hypothesis is not rejected. The statistics do not demonstrate a convincing association, for the age group studied, between children's age and their skills in coordinating colour organisation and 2D symmetrical pattern-making.	

COORDINATED COLOUR ORGANISATION AND SPATIAL PATTERNING: SUMMARY

At 3½ years, just one child evidenced skills in coordinating use of colour with a 2D symmetrical pattern. The coordination of colour organisation and linear symmetrical patterning was first evidenced in the data for children at 4½ years but again in just one child. The single child who coordinated colour with the symmetrical marking of a line did this as one aspect of a 2D symmetrical pattern.

At 4½ years, there was an increase from one to a small minority of children who evidenced skills in coordinating colour with their 2D spatial patterning. As a result of the small numbers of successful children at both ages, the statistics do not demonstrate a significant association between the age of children and their skills in coordinating colour organisation and spatial pattern-making for the age group studied.

At 4½ years, The five children who co-ordinated colour and spatial pattern-making made use of moderately complex colour organisation. Children co-ordinating colour organisation and spatial patterning at this age did not draw on the more advanced forms of colour organisation evidenced in the data from other assessment activities. This distinction between different levels of colour organisation is explored further and exemplified in the next chapter.

PATTERN PERCEPTION AND CHILDREN'S UNDERSTANDING OF THE WORD 'PATTERN' AT 3½ AND 4½ YEARS OF AGE

The evidence presented in this chapter has focused on children's skills in pattern-making at 3½ and 4½ and their procedural knowledge or 'routine-based knowledge' (Meadows 1993). It has not focused on children's pattern perception, or on children's understanding of the word 'pattern' and their declarative knowledge.

In the main study, most assessment activities focused on children's skills in pattern-making and on procedural knowledge. However, the main study research questions included a focus on other aspects of children's knowledge and understanding of pattern and these were

considered in research design. In particular, the introductory activity to the Teddy's Beads assessments was designed to gain access to children's understanding or perception of pattern. In addition, data arising from the Teddy's Beads 3 activity provided particularly useful evidence relating to children's declarative knowledge of pattern.

In the section that follows, qualitative data evidencing children's pattern perception, as well as their declarative knowledge and understanding of the word 'pattern', are presented. Firstly, children's use of language is analysed and secondly, the numerical data set is considered.

LANGUAGE DATA

The qualitative analysis draws on language data from the first activity in the Teddy's Beads set of assessments. It also draws on additional data relating to children's use of language, recorded during all assessment activities. Analysis focuses in turn on the evidence relating to pattern perception; to children's declarative knowledge and understanding of the word 'pattern' as relating to linear patterns; and to their declarative knowledge and understanding of the word 'pattern' as relating to 2D symmetrical patterns.

Pattern Perception

In the Teddy's Beads assessment activity, children were asked to express a preference for a bead sequence and to explain their choice. At 3½ and 4½ years, few children evidenced perception of pattern features through their choices or explanations. It is significant that during this key assessment activity, with children's attention focused on two simple patterns, no children made explicit reference to the word 'pattern'. The word 'pattern' had not been modeled during the activity.

In response to the request for an explanation of their choice, very few children made implicit or explicit reference to the organisation of colours within their preferred sequence, although colour organisation was the key feature of the bead patterns used. At both ages, when asked to explain their choice of necklace, the majority of children offered such unspecific responses as " 'cos I do" and "I like it". An increase in the number of specific explanations of preferences at 4½ years was the consequence of children's increased ability to focus on the colour of their preferred necklace. It was not a consequence of an increased ability to focus on colour organisation.

At 3½ years, three children made responses that implied some awareness of the significance of the organisation of colours within their preferred sequence. Two children pointed to the central yellow bead in the symmetrical pattern and one child verbalised the colour sequence of the repeated pattern, "Cos it's got green, yellow, green, yellow." Neither response, however, provides unambiguous evidence of pattern perception.

At 4½ years, there were no implicit responses of this kind. However, one child, Joseph, made explicit reference to the organisation of colours within the symmetrical pattern. Pointing to the yellow beads, Joseph explained, “Because its got two yellows there, two yellows there and a yellow there.”

Understanding of the Word ‘Pattern’ – Linear Patterns

During all main study assessment activities, children’s talk was recorded. Talk was often unrelated to ongoing activities but many children did talk about their work with beads, tiles and pegs. Analysis of this qualitative data indicates that many children, at 3½ and 4½ years were either unfamiliar with or puzzled by the word ‘pattern.’

Children, in their spontaneous talk, only rarely made use of the word ‘pattern.’ One context was an exception to this. This was the penultimate Teddy’s Beads assessment activity. In this activity, children were told that Betty bear “wants a necklace with a pattern on it.” They were then asked, “Can you make one with a pattern for baby bear?” This request, in contrast to other invitations to make a pattern, prompted many children at 3½ and 4½ years to make inquiries and comments about ‘pattern’. Comments and inquiries provide valuable evidence relating firstly, to children’s different understandings of ‘pattern’ and secondly, to the attempts of some children to make sense of the word.

Linear patterns - 3½ years

During the Teddy’s Beads activity, three children used the word ‘pattern’ to confirm that they intended to comply or had in fact complied with the request to make a pattern. However, there was no evidence of colour organisation in the bead sequences made. Lance, for example, reported, “There’s a pattern now,” after threading just three beads. Such comments alone provide no convincing evidence of understanding.

At 3½ years, one child indicated an awareness of his inability to comply with the request to make a pattern. John, who had responded positively to previous activities, reported, “Can’t do one of them.” The comment is ambiguous but it may indicate self-awareness in relation to a lack of understanding of ‘pattern’ as much as a lack of skill in pattern-making.

The responses of five children at 3½ years provide evidence of children attempting to make sense of ‘pattern’ as an unfamiliar colour term. Jim, for example, in response to the request to make a pattern, held up an orange bead, asking “These?” Sadie, at the same age, looked at the beads and asked, “Where’s a pattern?” while Amy confidently reported, “Can’t see any patterns.”

However, a small group of children at 3½ years did present some evidence of an appropriate and developing understanding of ‘pattern’. Rebecca, Laura and Nathan each made appropriate reference to a particular bead sequence as an example of pattern. In response to the request to make a pattern for Betty bear, each child asked, “Like that one?” pointing to a

repeating bead sequence. In addition, Christopher's comment evidenced a developing concept of pattern as a sequence incorporating several different colours. He responded to the request to make a pattern for Betty Bear with the comment, "I do different colours on it."

Linear patterns - 4½ years

A similar range of responses was observed at 4½ years. Just one child used the word 'pattern' to confirm an intention to comply with the request to make a pattern. Again, there was no evidence of colour organisation in the bead sequence made. At 4½ years, two children asked questions, indicating a lack of certainty about what 'pattern' might be. Lauren pointed to the beads in the tray, asking, "These?" and Amy asked, "What pattern?"

As at 3½, five responses evidence children attempting to make sense of 'pattern' as an unfamiliar colour term. Kieran for example, looking at the beads, asked, "Is it one of these?"

At 4½ just one child presented evidence of an appropriate and developing understanding of 'pattern' through reference to the model repeating bead sequence, "Like that?" Finally, four children, at 4½ years made comments, evidencing a developing concept of pattern as a sequence incorporating several different colours, perhaps a 'colourful' sequence. Christopher, at 4½ responded to the request to make a pattern for Betty Bear with a comment similar to his comment at 3½ years, "I'll do different colours." Joseph commented, "One with all different colours," and Karla responded, "With blue, purple, yellow, loads of other things, red." James asked which colours baby bear liked, making reference to several colours in turn and then commented, "He wants all different colours on... Have you got any more different colours?" In all four cases, children went on to make use of all available colours in their bead sequences. In each case, children actively searched for beads but did not make repeating or symmetrical sequences. It seems likely that these children were searching for one of each colour of beads in order to meet personal definitions of pattern.

Understanding of the Word 'Pattern' – 2D Symmetrical Patterns

Many children talked spontaneously about their work with pegs during the assessment activity. Analysis of the qualitative data relating to children's 2D spatial work again highlights children's understanding and their misunderstandings in relation to pattern.

Spatial patterns – 3½ years

Three children made reference to pattern while working with pegs. David who made a 2D spatial pattern commented, "Here's my pattern," at an early stage of working. He then became more excited about perceived representational features in his work, "It's a necklace... The car go round it..." Louise, having placed pegs for marking a 'rectangle,' commented, "I made a pattern." Finally, Jamie, having placed pegs for the first line of '10 parallel vertical lines,' commented, "I can make that pattern big, can't I?" All three children, at

3½ years, appeared to use the word ‘pattern’ with some awareness of their success or abilities in spatial patterning. In fact, both Louise and Jamie, while not combining elements of symmetry as 2D spatial patterns, did make individual configurations categorised in this study as basic elements of symmetry. During the pegboard activity, four children, including David, made reference to perceived representational features in their work. In fact, children at 3½ were as likely to articulate the perceived representational features of their spatial work as perceived mathematical features. However, the number of children in each group is small.

Spatial patterns – 4½ years

At 4½ years, eight children made references to pattern while working with pegs. This contrasts with the three references at 3½ years. However, there was a similar increase in the number of children using the language of representation to describe their work. At 4½ years, eight children talked about their work as if it was a picture.

Children’s ability to talk explicitly about pattern at 4½ years failed to match procedural knowledge. Dylan was in fact the only one, of the twelve children successful in making 2D symmetrical patterns, who made reference to pattern during work with pegs. Two of the children who made 2D symmetrical patterns talked only about the representational features of their work. James, whose work is illustrated in Figure 5.28, talked about each element of his pattern as a body part, “Done face and I’ve done legs... Going to do its arms first... I’ve done three eyes.” Similarly, Rona, completing a complex sequence of repeated patterns, commented, “I’ve been making a firework.” In contrast, Joseph, having completed his work used both representational and mathematical language to describe it, “That way it’s a kite and that way it’s a cross.” One child, Jon, showed some confusion about the distinction between patterns and pictures, “I’m making a door pattern.” As at 3½ years, just a small group of children appeared to use the word ‘pattern’ with an appropriate awareness of their competencies in relation to the spatial organisation of materials.

NUMERICAL DATA

Numerical data provides further evidence relating to children’s skills in the perception of linear patterning at 3½ and 4½ years of age. It also provides evidence of children’s knowledge about some key elements of linear patterning

Table 9.11 Teddy’s Beads – proportional success in indicating a preference for a sequence

	repeated pattern	symmetrical pattern	random arrangement	no preference indicated
3½ years (N = 49)	42.9%	18.3%	16.3%	22.5%
4½ years (N = 49)	30.6%	20.4%	38.8%	10%

Table 5.12 Teddy's Beads – proportional success in explaining a preference for a sequence

	No specific explanation	Specific explanation		
3½ years (N = 49)	79.6%	20.4%	14.3%	Reference to 1 or 2 specific colours
			4.1%	Indication of the central bead (symmetrical pattern)
			2%	Verbalization of the colour sequence (repeating pattern)
			0%	Reference to elements of symmetry
4½ years (N = 49)	57.1%	42.9%	40.8%	Reference to 1 or 2 specific colours
			0%	Indication of the central bead (symmetrical pattern)
			0%	Verbalization of the colour sequence (repeating pattern)
			2.1%	Reference to elements of symmetry

3½ years

At 3½ years, when asked to express a preference for a bead sequence, a majority of children expressed a preference for a repeated pattern. However, at 4½ years, the majority expressed a preference for a random arrangement. The study provides no evidence of progression in the responses of the two age groups in terms of children's expressed preferences. It therefore seems likely that the choices of many children at 3½ years were unrelated to key features of selected bead sequences.

At 3½ years a large majority of children were unable or unwilling to offer a specific explanation, verbal or nonverbal, for their choice of bead sequence. The small group of children who did explain their preference was most likely to make reference to one or two colours as explanation for their choice. At this age, only a very small group of children offered verbal or nonverbal explanations which evidence perception of pattern features.

4½ years

At 4½ years, the largest group of children expressed a preference for the random arrangement of beads. Their choice suggests an absence of perception of pattern features. However, more than half the sample expressed a preference for either the repeating or the symmetrical pattern sequence.

There is evidence of an increase between assessment periods in the percentage of children willing to express a preference for a particular bead sequence. However, at 4½ years, a small minority of children remained unwilling or unable to express a preference. Additionally, a larger group of children at 4½ years made reference to one or two colours, as an explanation for their choice of bead sequence. In both age groups, this was the most frequently offered explanation. However, at 4½ years, as at 3½ years, only a very small group of children offered verbal or nonverbal explanations evidencing perception of pattern features.

SUMMARY: PATTERN PERCEPTION AND CHILDREN'S UNDERSTANDING OF THE WORD 'PATTERN'

3½ years

For most children, at 3½ years, the study presents no positive evidence of pattern perception. However, for a very small group of children, there is evidence suggestive of an implicit awareness of at least one key feature of pattern. Two children demonstrated an implicit awareness of the significance of the central point in a symmetrical pattern. A third child demonstrated an implicit awareness of the significance of the sequence of colours in a repeating sequence.

For most children at 3½ years the word 'pattern' seemed to be an unfamiliar word. There was no evidence of children using the word 'pattern' spontaneously, even when attention was focused on simple examples of patterned bead sequences. However, several children, at 3½ years did make use of the word 'pattern' when talking to an adult who had modeled this word. For many of these children, the use of the word 'pattern' was a part of their attempt to make sense of it, testing their hypothesis that 'pattern' was an unfamiliar colour word.

A small group of children at 3½ years did present some evidence of a developing and appropriate understanding of pattern, making reference to a repeating bead sequence in response to an adult's use of the word. One child evidenced a more explicit understanding of pattern as a sequence of several different colours, but without reference to the organisation of colours within the sequence. Additionally, three children evidenced a developing understanding of the word pattern in the context of spatial patterning, using the word to refer to their pegboard configurations.

4½ years

For the majority of children at 4½ years, the study presents little positive evidence of pattern perception. Just one child, Joseph, made explicit reference to the organisation of colours within a pattern. For many of the children at 4½ years, the word 'pattern' still seemed to be an unfamiliar word. Again no children used the word 'pattern' spontaneously, except in response to an adult's use of the word. As at 3½, several children used the word 'pattern' during work with

beads, attempting to make sense of it and testing the hypothesis that 'pattern' was an unfamiliar colour word. Just one child presented evidence of an appropriate and developing understanding of 'pattern' through reference to the repeating bead sequence. Additionally, four children at 4½ years evidenced a developing but unconventional concept of pattern as a sequence incorporating several different colours.

At 4½ years, an increased group of children used the word 'pattern' in the context of spatial patterning, using the word to refer to their pegboard configurations. However, there was a similar increase in children's references to their work as representations, even where work successfully coordinated elements of symmetry.

Conclusion

To conclude, this chapter has presented a wide range of evidence relating to the first research question, focusing on the pattern-related knowledge, understanding and skills of young children at 3½ and 4½ years. It has presented evidence of significant increases in the range of pattern-making skills and in procedural knowledge for children at 4½ years, as compared to children at 3½ years. Additionally, it has presented evidence suggesting that the general increase in children's pattern-making skills and procedural knowledge at 4½ years, as compared to 3½ years, is not matched by similar increases in children's declarative knowledge or perception of pattern.

The evidence relating to young children's pattern-making knowledge, understanding and skills at specific points in development, 3½ and 4½ years, has been examined. Chapter 6 moves on to focus on the details of children's development during this period. It includes a new focus on the patterning play that may provide a foundation for the pattern-making competencies of a minority of advanced children at 3½ and 4½ years, as exemplified in this chapter.

CHAPTER 6

PRESENTATION AND ANALYSIS OF RESULTS: DEVELOPMENT IN PATTERN-MAKING

INTRODUCTION

Chapter 5 evidenced a range of significant and interesting differences in the nature and extent of the knowledge, understanding and skills in pattern-making of children at 3½ and 4½ years. Firstly, quantitative data evidenced a significant increase in the number of children demonstrating knowledge, understanding or skills in pattern-making at 4½ years, as compared to children at 3½ years. Secondly, a small group of children demonstrated more secure and more flexible skills at 4½ years than were demonstrated by children at 3½ years. Thirdly, a small group of children, at 4½ years, demonstrated skills in devising patterns that were different to and in some cases more complex than the patterns made by main study children at 3½ years.

The analysis of data in Chapter 5 also confirmed some of the findings of earlier studies, findings of young children's limited skills in copying, continuing and devising repeating patterns, particularly at 3 years of age. The findings of this study are that only a very small group of children at 3½ years and an enlarged minority at 4½ years demonstrate knowledge, understanding and skills in repeated pattern-making. The findings in relation to spatial pattern-making are similar.

Nevertheless, despite the relatively small numbers of children demonstrating knowledge, understanding and skills in the two strands of pattern-making at 3½ and 4½ years, the majority of children participated happily in assessment activities from the earliest age. In almost all cases, young children were motivated to devise arrangements of play materials and many children talked about their work, often thinking aloud about work in progress. In some cases, although work did not meet pattern-making assessment criteria, children proudly labeled their arrangements of play materials as patterns and some children commented on how good they were at making patterns.

Such observations, as well as main study findings in relation to the first research question, prompt reflection on the question of development. They prompt consideration of the possibility that there may be an identifiable early period of development within the strands of colour organisation and spatial organisation, prior to pattern-making but leading towards knowledge, understanding and skills in pattern-making. Main study findings also support reflection on the nature of the more advanced development that may take place between 3½ and 4½ years for the small minority of children who demonstrate early knowledge, understanding and skills in pattern-making at 3½ years.

Such reflections lead into a consideration of the second research question focused on these issues:

2. Where do knowledge, understanding and skills in pattern-making begin and how do they develop between the ages of 3½ and 4½ years?

Reflection on issues of development in pattern-making raises the possibility of developmental pathways in common to many or all children. It also leads into consideration of the third and fourth research questions:

3. Are there individual differences in the detailed pathways taken towards knowledge, understanding and skills in pattern-making?
4. Are there individual differences in knowledge, understanding and skills in pattern-making and in rates of development between 3½ and 4½ years?

While the second question focuses on the possibility of generalised developmental pathways towards and within pattern-making, the third and fourth questions highlight the importance of a complementary examination of possible differences in the development of individuals.

TOWARDS PATTERN-MAKING: DEVELOPMENT BETWEEN THE AGES OF 3½ AND 4½ YEARS

To answer the set of research questions above in terms of children's knowledge, understanding and skills in the two strands of pattern-making, it is necessary to focus on two key aspects of development. Firstly, it is necessary to focus on the earliest stages in young children's developing knowledge, understanding and skills, leading towards early levels of competence in pattern-making. In following this direction, it is important to acknowledge that the early stages in the developmental process may be critical to later development, but may look very different to later competencies. For example, researchers (Cox 1997) have identified an early 'scribbling' stage in the development of children's drawing skills, functioning as an important stage in the developmental process. However, the scribbling of a child of just 3 looks very different to the figure drawing of a mature 4 year old.

Secondly, the research questions under consideration lead to a focus on the identification of the stages between early competence in pattern-making and the more advanced levels of knowledge, understanding and skills demonstrated by groups of children at 4½ years.

In the section that follows these aspects of development are considered in two ways. Firstly, the qualitative data from assessment activities and from additional case-study material are examined in order to illuminate the developmental pathways followed by children towards and within repeated and spatial pattern-making. Secondly, hypothesised pathways, arising from analyses, are re-examined in the light of the numerical and quantitative data yielded by main study assessment activities. Statistical analysis is used to test key features of the hypothesised pathways. Finally, for repeated pattern-making only, a further case-study is used to examine some features of within level development in the colour organisation strand of pattern-making.

CASE STUDY DATA

A longitudinal study was set up to track the development of a group of 24 children from 3½ to 4½ years of age. In this chapter, aspects of the development of eight of the children from the longitudinal study are examined in a detailed way through the analysis of qualitative assessment data, collected at four points over the year. Additional case study data, collected in the context of self-initiated play during the nursery session, is also examined.

The eight children were selected to ensure that a range of data was drawn upon, with exemplification of the earliest and the most advanced stages of the observed development towards and within pattern-making. Case study data from seven of the eight children are presented to exemplify the range of development in colour organisation and six of the eight children to exemplify development in spatial organisation.

The analysis in this chapter focuses on:

- two children in low groups for both spatial and colour organisation – Aaron and Lauren
- one child in a medium group for both spatial and colour organisation – Andrew
- one child in a medium group for colour organisation - Gemma
- one child in a medium group for spatial organisation and a high group for colour organisation - Rona
- one child in a high group for spatial organisation - James
- one child in a high group for spatial organisation and a high group for colour organisation – Dylan

At a later stage in the analysis of colour organisation data, an additional child, meeting the following criteria, was selected for inclusion in the colour organisation strand of the study.

- one child in a high group for colour organisation who appeared to work at a similar level throughout assessment periods - Christopher

The different strands of children's development towards knowledge, understanding and skills in pattern-making are considered at different points in this chapter. Analysis begins with a focus on development within the colour organisation strand of pattern-making. The later part of the chapter focuses on development within the spatial organisation strand of pattern-making.

Examples from the work of the initially selected children are presented to illuminate the individual pathways followed, both towards and within the two strands of pattern-making. Additionally, examples from the work of an additional child are presented to illuminate development towards and within the colour organisation strand of pattern-making. Work is analysed in relation to the key features of colour or spatial organisation observed. In most cases, at least one example of colour and spatial organisation is presented for each child from each of the four assessment periods. Examples are selected to represent the most complex forms of

organisation observed. Further examples are presented where exemplified work provides additional evidence of progression. Relevant background and contextual information are provided.

COLOUR ORGANISATION: DEVELOPMENT BETWEEN THE AGES OF 3½ AND 4½ YEARS?

Firstly, to examine the three key research questions in terms of the colour organisation strand of pattern-making, qualitative case study data are presented. Secondly, an hypothesised developmental pathway towards and within repeated pattern-making is outlined. Thirdly, the hypothesised developmental pathway is examined in the light of the numerical and quantitative data relating to the colour organisation strand of pattern-making.

COLOUR ORGANISATION: CASE STUDY DATA

Recording colour organisation

The recording system used in this chapter for the representation of colour organisation follows the conventions outlined in the previous chapter, with one addition. Where categorisation and analysis is focused on one part of a child's sequence of play materials rather than the complete sequence, underlining is used to highlight the focus section. The work illustrated represents each child's most complex work for the age unless otherwise stated.

Aaron

3 years 6 months

By the time of the first assessments, Aaron had settled happily at nursery. He was happy to take part in a range of activities, usually following the lead of his cousin, Lisa. Aaron needed some help with threading during the first assessment activities. His attention seemed focused mainly on mastering the necessary fine motor skills. He did not appear to be attentive to the particular beads selected and was mainly silent during practical activities.

The example below is characteristic of Aaron's work at this age in terms of observed colour organisation.

Colour organisation – selecting play materials without evidence of attention to colour

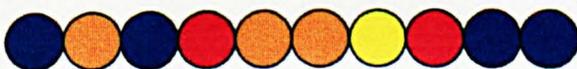


Figure 6.1 Aaron: Teddy's Beads 1 at 3 years. 6 months

At 3 years 6months, Aaron was not observed organising play materials in terms of their colour attributes and he was not observed talking about colours.

3 years 11 months

By this age, Aaron was showing increased independence and confidence at nursery. He had recently shown some knowledge of colour names during nursery activities and nursery records show one example of spontaneous colour naming in the context of self-initiated play. Aaron was now happy to chat to the adult during assessment activities. He showed increased interest in the Bead Threading activity, asking, "Can I get this home with me?"

Colour organisation - grouping of similar play materials

During this activity, Aaron used colour names for the first five tiles and the last tile placed. Some tiles were named correctly and some incorrectly. After placing twelve tiles, Aaron removed the first tile placed and said, "Take blue off." He then replaced the blue tile with a black tile, saying "other black."



Figure 6.2 Aaron: Mosaic Tiles 2 at 3 years 11 months

At 3 years 11 months, Aaron was not observed organising play materials in terms of their colour attributes during any other assessment activities. However at this age, his progress is evident in terms of his new interests, firstly in grouping play materials by colour and secondly, in colour naming.

4 years 2 months

By 4 years 2 months, Aaron had mastered threading skills. During bead threading, however, his attention was focused on the length of his bead sequence rather than on colour organisation, "I'm making a big one... Look big!"

Colour organisation – sustained grouping of similar play materials

Before starting to place tiles, Aaron pre-selected some black tiles and further active searching was observed. Aaron said, “I’m making black,” while placing tiles. He correctly named several black tiles but incorrectly named a red tile as black



Figure 6.3 Aaron: Mosaic Tiles 1 at 4 years 2 months

Colour organisation – sustained grouping of similar play materials

Before starting to place tiles, Aaron stated, “I’m going to do black, red, black”. Active searching was observed and Aaron talked about the black tiles as he worked, “Don’t know where to put black...I’ve got two blacks...Need two blacks.” On completing the sequence, he said, “I’ve done two blacks.”



Figure 6.4 Aaron: Mosaic Tiles 2 at 4 years 2 months

At 4 years 2 months, Aaron was not observed organising play materials in terms of colour attributes during any other assessment activities. However, the examples above evidence Aaron’s progression within the colour organisation strand of pattern-making in a number of ways. Firstly, Aaron sustains his grouping of play materials by colour for groupings of six and eight components. Secondly, he shows a new interest in the numerosity of play materials and in the use of number words, although he does not use these accurately. Finally he plans verbally, “I’m going to...,” although not all aspects of his plan are implemented.

4 years 6 months

Colour organisation – alternating similarity groups and units of play materials

Aaron was observed searching for particular tiles. He worked without talking.



Figure 6.5 Aaron: Mosaic Tiles 2 at 4 years 6 months

The example above evidences Aaron's progression in colour organisation from a focus on relationships of similarity to a sustained and co-ordinated focus on relationships of similarity and difference.

At 4 years 6 months, assessment data show Aaron continuing to make use of the forms of colour organisation observed at earlier assessment periods. There are, however, further indicators of Aaron's progress in terms of the colour organisation strand of pattern-making. Firstly, Aaron sustains sorting by colour in an increased number of contexts. He sustains colour sorting in two of the 'Teddy's Beads' activities, as well as in work with tiles. Secondly, Aaron demonstrates early planning skills in an increased range of contexts. In Teddy's Beads 2, he says, "I'm having these ones," and pre-selects five green beads before starting to thread. In Mosaic Tiles 1, he says, "I'm having all blacks," as he pre-selects seven black tiles.

Progression is also evident in terms of Aaron's dispositions for learning. At the start of the year, case-study data provides no evidence that dispositions for learning were well established. However, by the end of the year, case study data shows Aaron working in a committed way in most assessment contexts, as well as in many other nursery contexts.

Lauren

3 years 6 months

After a difficult start, Lauren had settled happily at nursery by the time of the first assessments. She still, however, showed reluctance on occasions to attempt new activities, saying for example, "I can't do it," before starting to thread beads. Lauren in fact had no difficulties at this time with threading skills. Although she was initially reluctant to participate in some assessment activities, on each occasion Lauren's confidence and enjoyment grew as she worked alongside the adult.

Lauren particularly enjoyed the Teddy's Beads activities. However, during this set of activities Lauren's attention was intently focused on the imaginative features of the play setting, and not on colour organisation.

Colour organisation – colour naming of a single component of play materials

Lauren said, “red,” as she placed her first tile. No active searching was observed during this activity.



Figure 6.6 Lauren: Mosaic Tiles 2 at 3 years 6 months

At 3 years 6 months, a further example of Lauren’s interest in colour naming was observed during Teddy’s Beads 4. A yellow bead was named, although incorrectly. At this age, Lauren was not observed organising play materials in terms of their colour attributes in any other context.

4 years

At 4 years, Lauren engaged happily in assessment activities and chatted to the adult during activities. Her talk, however, was entirely related to extraneous events, for example who was going to collect her from nursery.

At this age, Lauren was not observed organising play materials in terms of their colour attributes in any context.

4 years 4 months

Colour organisation – alternating similarity groups and units of play materials

During this activity, Lauren was observed searching actively for tiles. Her attention seemed to be focused closely on the colours selected. For example, she said, “I love them uns,” as she placed the two blue tiles. She used some colour names, with some tiles named correctly and some incorrectly.



Figure 6.7 Lauren: Mosaic Tiles 2 at 4 years 4 months

The example above indicates Lauren’s progression in terms of colour organisation, from a focus on colour naming to a co-ordinated focus on relationships of similarity and difference. Lauren’s continuing interest in colour naming is indicated by her request for a colour name in a new context. While threading beads, Lauren held up a yellow bead and asked, “What’s this one

called?" At this age, Lauren was not observed organising play materials in terms of their colour attributes in any other context.

4 years 6 months

Colour organisation – repeating a difference group of play materials – 1 error

At the start of the activity, Lauren checked out her understanding of the instruction to make a necklace 'just the same as Betty's necklace.' She pointed to Betty bear's necklace, asking, "Same as these?" Active searching was observed.



Figure 6.8 Lauren: Teddy's Beads 1 at 4 years 6 months

The example above evidences Lauren's further progression in the colour organisation strand of pattern-making. Lauren successfully co-ordinates foci on relationships of similarity and difference in the new context of bead threading. During this activity, Lauren also evidences an understanding of the relevant mathematical language, 'same as', for the first time. Additionally, at 4 years 6 months, Lauren groups play materials in terms of similarity relationships in a sustained way during the Teddy's Beads 2 activity. Although not successful in continuing the repeating pattern on the 'broken' necklace, she was successful in continuing to select one of the two colours used. At this age, Lauren was not observed organising play materials in terms of their colour attributes in any other context.

At 4 years 6 months, Lauren's most complex work, in terms of the observed features of colour organisation, matches that observed two months earlier. However this work was undertaken in a new context. Progression, but relatively limited progression, is also evident by 4 years 6 months in Lauren's dispositions for learning in this curriculum area. At the start of the study Lauren was sometimes reluctant to engage in new activities. This changed as she grew in confidence. However, during the later assessment periods, Lauren sometimes seemed to engage only superficially with assessment activities. At times, this was because of Lauren's anxieties about extraneous events. Sometimes, however, this was because of her ambivalence in relation to the focus activities. Generally, Lauren preferred imaginative and more sociable activities.

Andrew

3 years 7 months

Andrew had settled happily at nursery by the time of the first assessments and was confident about participating in a wide range of activities. Andrew talked about what he was

doing during some of the assessment activities but without reference to colour. In work with tiles, his attention seemed to be focused instead on the length and representational features of his sequence. "I'm making a big snake." Active searching was not observed during assessments. The example below is characteristic of Andrew's work at this age, in terms of observed colour organisation. At 3 years 7 months, Andrew was not observed organising play materials in terms of their colour attributes.

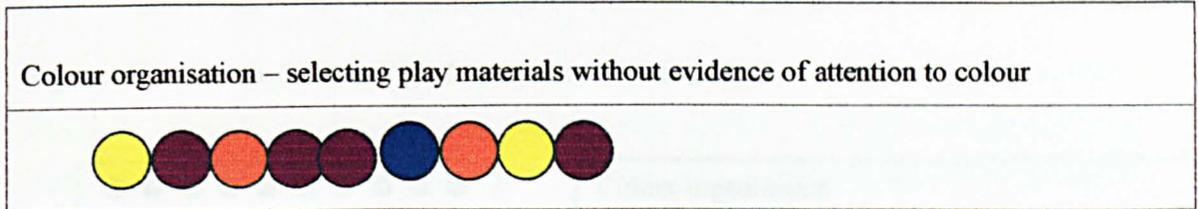


Figure 6.9 Andrew: Teddy's Beads 1 at 3 years 7 months

3 years 11 months

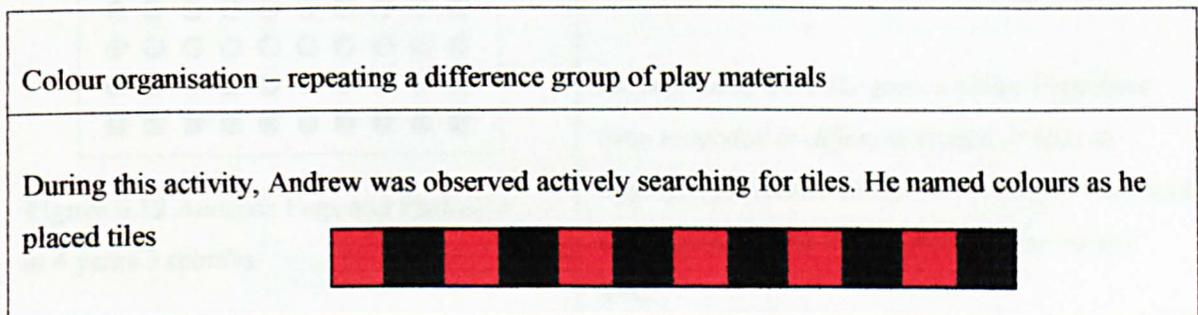


Figure 6.10 Andrew: Mosaics Tiles 2 at 3 years 11 months

The example above evidences significant progress for Andrew in the colour organisation strand of pattern-making. Andrew appears to progress from selecting play materials without any focus on colour attributes, at 3 years 7 months, to a sustained and co-ordinated focus on relationships of similarity and difference, alongside a consistent focus on the numerosity of groupings, at 3 years 11 months.

At 3 years 11 months, Andrew was observed organising play materials in terms of their colour attributes in one other assessment context. During Bead Threading he named the colour of a bead and grouped some beads of the same colour together.

4 years 3 months

The examples below represents Andrew's more complex work at this age, in terms of the observed features of colour organisation.

Colour organisation – chaining similarity groups of play materials

During this activity, Andrew was observed searching actively for tiles. He named colours as he placed tiles



Figure 6.11 Andrew: Mosaic Tiles 2 at 4 years 3 months

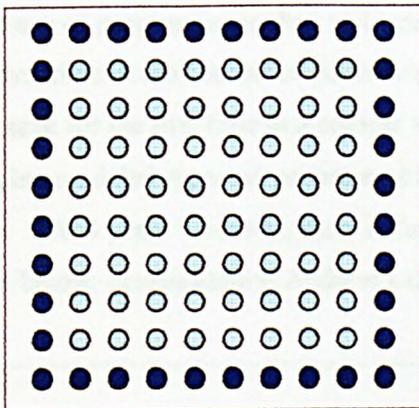


Figure 6.12 Andrew: Pegs and Pegboard at 4 years 3 months

Colour organisation

- 2D grouping of similar play materials

Andrew commented, “I’m doing them all blue,” half way through working on his pegboard.

All pegs used were the same colour. Pegs have been recorded in different shades of blue to highlight placement order. A ‘rectangle’ was made and this was filled with ‘8 parallel horizontal lines.’

Andrew’s pegboard was probably intended to be a replica of a pattern made previously, at 4 years 1 month, during self-initiated play. Andrew recalled this earlier work as he worked on this pattern, “You know when I did all those in blue and you took a picture with your camera.” Nursery records include an observation of this earlier work, confirming similarities in both colour and spatial organisation.

At 4 years 3 months, Andrew’s most complex linear work appears to be less complex than that observed at 3 years 11 months. At this age there is no focus on repeated groupings or the numerosity of groupings, evident in Andrew’s work with mosaic tiles at 3 years 11 months. However, there is evidence of progression in colour organisation in Andrew’s new devising skills. Andrew’s response to Mosaics 2 may be an intentional rejection of a modeled pattern in favour of a sequence incorporating what seemed to be his favourite colour at the time, blue. There is additional evidence of progression in Andrew’s ability to reproduce a remembered pattern in pegboard work. Finally, there is evidence of progression in terms of Andrew’s new focus on colour organisation in a 2D context.

4 years 7 months

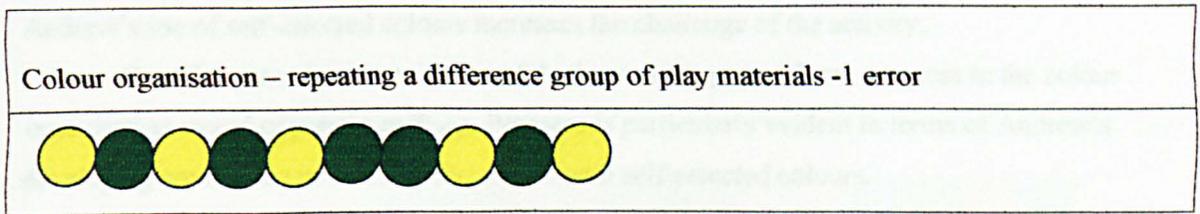


Figure 6.13 Andrew: Teddy's Beads at 4 years 7 months

The work above is similar in terms of colour organisation to that observed some time earlier, at 3 years 11 months. Andrew's work in Teddy's Beads 1 does, however, provide some evidence of progression in that, at 4 years 7 months, this form of colour organisation is seen for the first time in the context of Andrew's work with beads. This form of colour organisation is also seen for the first time in a context where Andrew is copying a physical model, rather than copying modeled repeated pattern-making.

At 4 years 7 months, there is further evidence of progression in the two examples of work below, demonstrating Andrew's developing skills in devising colour sequences.

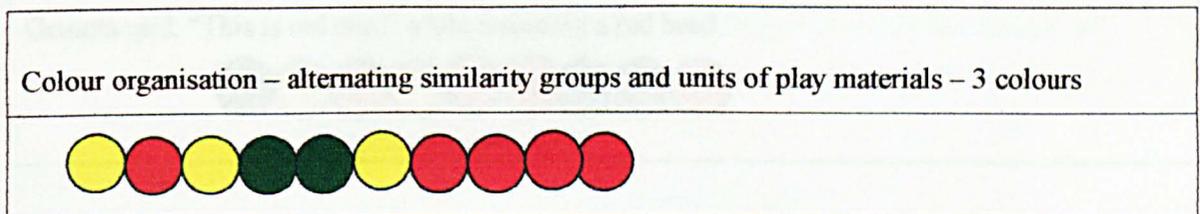


Figure 6.14 Andrew: Teddy's Beads 4 at 4 years 7 months

In Teddy's Beads 4, Andrew co-ordinates the alternation of 3 colours for the first time, responding to the invitation to make a pattern with red, green and yellow beads.

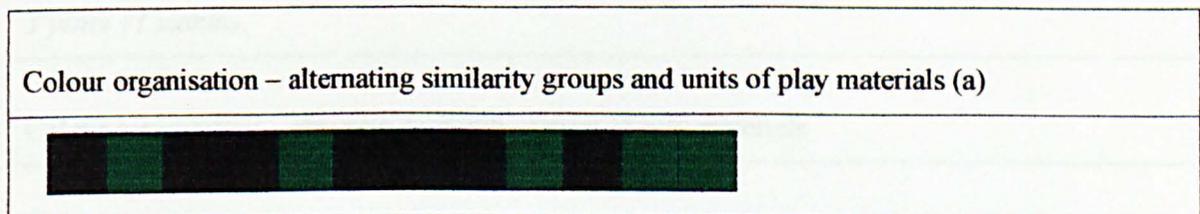


Figure 6.15 Andrew: Mosaics 2 at 4 years 7 months

The work above in one way seems less complex than Andrew's earlier response to Mosaics Tiles 2. In contrast to work at 3 years 11 months, Andrew does not focus consistently on the numerosity of alternated groupings. However, at 4 years 7 months, Andrew does choose to work

with self-selected colours rather than the colours modeled by the adult. It seems likely that Andrew's use of self-selected colours increases the challenge of the activity.

Over the year, there is evidence of Andrew making significant progress in the colour organisation strand of pattern-making. Progress is particularly evident in terms of Andrew's developing confidence in devising sequences with self-selected colours.

Andrew demonstrated positive dispositions for learning throughout the study and had wide-ranging interests. From first starting at nursery, he choose to work independently with the kinds of play materials used in the study

Gemma

3 years 6 months

Gemma settled quickly and happily at nursery. By the time of the first assessments, she was confidently participating in a range of activities.

Colour organisation – colour naming of a single component of play materials

Gemma said, "This is red one," while threading a red bead

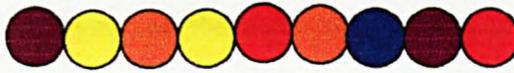


Figure 6.16 Gemma: Teddy's Beads 1 at 3 years 6 months

Gemma also demonstrated an interest in colour naming and correctly named a red bead while threading beads for Teddy's Beads 2.

3 years 11 months.

Colour organisation – chaining similarity groups of play materials

Gemma named colours as tiles were placed. Active searching was observed.



Figure 6.17 Gemma: Mosaic Tiles 1 at 3 years 11 months

Colour organisation – alternating similarity groups and units of play materials

Gemma said, “red,” before starting and named colours as tiles were placed. Active searching was observed.



Figure 6.18 Gemma: Mosaics 2 at 3 years 11 months

During this period, Gemma also chained similarity groups of play materials during self-initiated play with wooden bricks. Nursery records show her making a tower of bricks, sorting the bricks by colour until the tower fell (6 red, 5 green and 4 yellow).

Additionally, at 3 years 11 months, Gemma named and commented on similarities amongst some of the different colours of components of play materials during the Pegs and Pegboard assessment activity.

At 3 years 11 months, Gemma’s progress is evident in the change from a focus on the colour of an individual component to a sustained and co-ordinated focus on relationships of similarity and difference. Secondly progress is evident in terms of the increased number of contexts in which Gemma uses the more complex forms of colour organisation.

4 years 2 months

Colour organisation – repeating a difference group of play materials (a)

Gemma said, “red, black, red,” as she placed tiles. Active searching was observed.



Figure 6.19 Gemma: Mosaics 2 at 4 years 2 months

A further example of complex colour organisation was observed in Gemma’s 2D work with pegs. This is illustrated in the section relating to the coordination of colour and spatial organisation.

At 4 years 2 months, Gemma’s progress in colour organisation is evident in terms of her new and consistent focus on the numerosity of groupings, co-ordinated with the focus on relationships of similarity and difference, previously observed at 3 years 11 months.

4 year 6 months.

Colour organisation – repeating a difference group of play materials

Gemma worked without talking. Active searching was observed.



Figure 6.20 Gemma: Mosaics 1 at 4 years 6 months

Colour organisation – repeating a difference group of play materials

Gemma said, "red," as she placed the first tile. Active searching was observed.



Figure 6.21 Gemma: Mosaics 2 at 4 years 6 months

Colour organisation – repeating a difference group of play materials

Gemma did not refer back to the model while working. Active searching was observed.

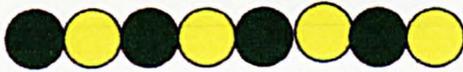


Figure 6.22 Gemma: Teddy's Beads 1 at 4 years 6 months

At 4 years 6 months, Gemma used this form of colour organisation in one further new assessment context. In Teddy's Beads 2, she continued a repeating pattern. Gemma also used this form of colour organisation, coordinated with a 2D spatial pattern, during self-initiated play with pegs.

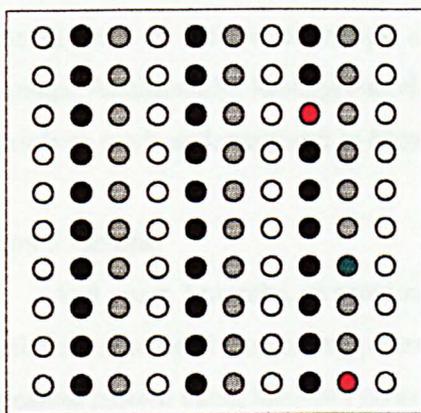
The most complex colour organisation observed at 4 years 6 months matches that seen earlier, at 4 years 2 months. There is, however evidence of progression in terms of the greatly increased number of contexts in which Gemma uses this form of colour organisation. In particular, there is evidence of progression in terms of Gemma's newly developed skills in devising patterns.

Over the year, progression is also evident in terms of Gemma's dispositions for learning in this area of the curriculum. These were well established at the beginning of the study. However, responding to home difficulties, Gemma became relatively solitary at nursery during this period. She was increasingly attracted to quieter work with pattern-making materials over the year and regularly engaged in concentrated self-initiated play.

Rona

3 years 7 months

Rona was settled happily at nursery by the time of the first assessments. She was a relatively solitary child initially and particularly enjoyed playing alone with toys such as beads and jigsaws.



Colour organisation

- identifying play materials of different colours
- identifying play materials of similar colours

Rona named some colours as she placed pegs, "That's a white one... That's a green one... White one again... That's a red one."

Figure 6.23 Rona: Pegs and Pegboard at 3 years 7 months

Colour organisation – identifying play materials of similar colours

Rona talked about a pair of purple beads in the pile which she had pre-selected, "And them purple beads."

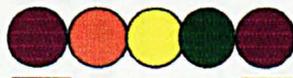


Figure 6.24 Rona: Teddy's Beads 4 at 3 years 7 months

Additionally, at 3 years 7 months, Rona identified similar and different coloured play materials during Bead Threading. She also identified a blue bead in Teddy's Beads 1, "I've got blue."

4 years

Colour organisation – repeating a difference group of play materials

During this activity, Rona was observed actively searching for tiles. She named the colours as she placed tiles



Figure 6.25 Rona: Mosaic Tiles 1 at 4 years

The example above shows Rona's significant progress in terms of colour organisation, from a focus on discrete relationships of similarity and difference, to a sustained and coordinated focus on such relationships, alongside a consistent focus on the numerosity of groupings. Additionally, Rona grouped or identified similar and different coloured play materials in work with pegs and in Mosaic Tiles 2.

4 years 3 months

At 4 years 3 months, as previously, Rona's more complex work, in terms of colour organisation, included a repeating pattern using black and red tiles in Mosaics 1. She also made a repeating pattern using blue and green tiles in Mosaics 2. At this age, progression is evident in terms of the increased number of contexts, from one to two, in which Rona makes repeated patterns. Additionally, progression can be observed in Rona's increased fluency in devising patterns using new colour combinations.

4 years 7 months

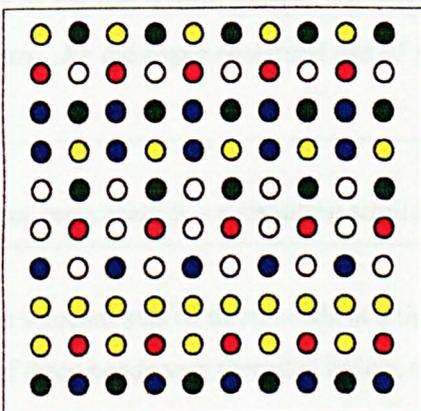


Figure 6.26 Rona: Pegs and Pegboard at 4 years 7 months

Colour organisation

- chaining lines of repeated difference groups of play materials

Rona chatted as she worked but talk was mainly unrelated to the activity. She did, however talk about both her and her sister's favourite colours. Rona scanned the pegboard at several points while working. She may have been checking to ensure that the combination of colours in each line was different to that of the preceding line.

More ambitiously, Rona may have been aiming at a different combination for each row. Although this was not achieved, she did use seven of the ten possible colour combinations in the nine lines of repeated patterns devised

Colour organisation – repeating a 6 unit difference group of play materials

During this activity, Rona was observed actively searching for tiles. She did not talk about the pattern.



Figure 6.27 Rona: Mosaic Tiles 2 at 4 years 7 months

Just prior to this assessment, Rona had made a similar pattern to that above during self-initiated play with beads. Her consistent focus on the numerosity of repeated groupings, first observed at 4 years, is here extended from groupings of two, to a grouping of six.

Additionally, at 4 years 7 months, Rona copied, continued and devised repeating patterns in a number of contexts. In Teddy's Beads 1, she successfully copied the green and yellow pattern, and in Teddy's Beads 2, she successfully continued this pattern. In Teddy's Beads 3, Rona devised a repeating pattern, using red and orange beads. She also devised a repeating pattern, using green and blue beads in the Bead Threading activity.

In Teddy's Beads 4, Rona attempted to make a pattern incorporating 3 colours. She successfully focused on the numerosity and the colours of each group but did not focus on the order of colours within groups. Although unsuccessful in devising a repeating pattern with 3 colours, she did make sustained use of the three colours, as exemplified below.

Colour organisation – alternating similarity groups and units of play materials

Rona selected sets of three beads at a time, with a red, green and yellow bead in each group. Each set of three beads was threaded before another set was selected

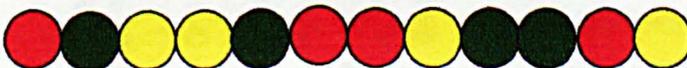


Figure 6.28 Rona: Teddy's Beads 4 at 4 years 7 months

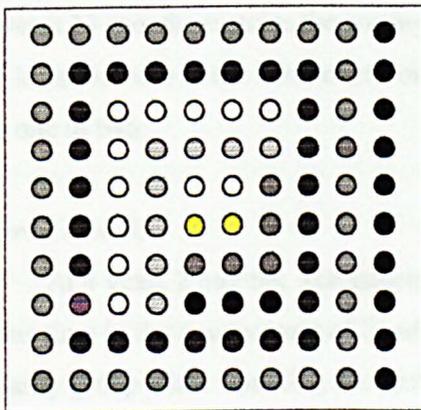
At 4 years 7 months, there is evidence of Rona having made significant progress in terms of the colour organisation strand of pattern-making. Firstly, progression is evident in the increasingly complex forms of colour organisation attempted and demonstrated. Secondly, progression is evident in terms of the increased number of contexts that Rona uses for the more complex forms of colour organisation.

Rona demonstrated positive dispositions for learning, particularly in this area of the curriculum, and growing self-confidence during the period of the study.

Dylan

3 years 6 months

Dylan had settled quickly and happily at nursery. He enjoyed a wide range of nursery activities but particularly enjoyed active outdoor play. He was generally reluctant to engage in mark-making activities.



Colour organisation

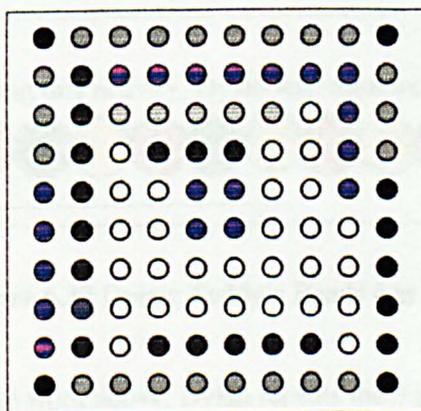
- grouping similar play materials

Dylan commented, "They're eyes," as he placed a second yellow peg, as a part of 'marking the centre.'

Figure 6.29 Dylan: Pegs and Pegboard at 3 years 6 months

At 3 years 6 months, Dylan was not observed organising play materials in terms of their colour attributes in any other context and he was not observed talking about colours.

3 years 11 months



Colour organisation

- grouping of similar play materials

During this activity, Dylan was observed actively searching for blue pegs.

Dylan commented, "I got blue," as he placed a blue peg in first group of blue pegs.

Figure 6.30 Dylan: Pegs and Pegboard at 3 years 11 months

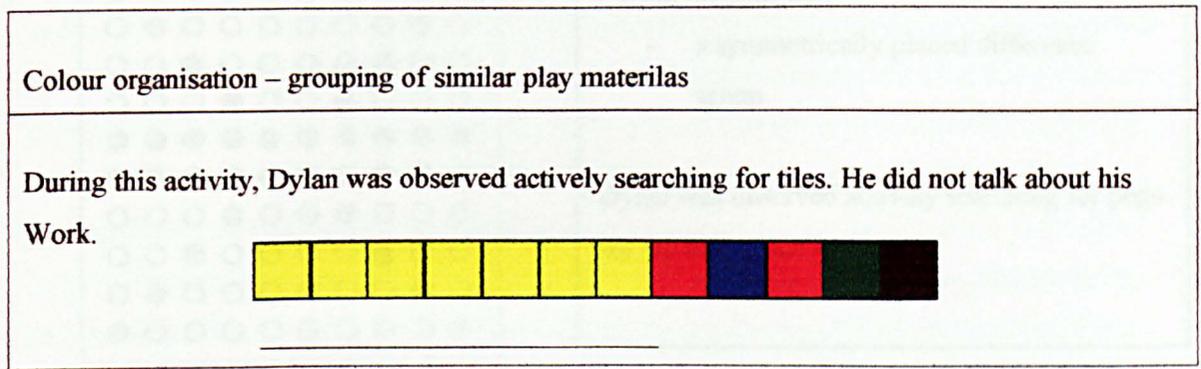


Figure 6.31 Dylan: Mosaic Tiles 2 at 3 years 11 months

At 3 years 11 months, Dylan's most complex work, in terms of colour organisation, is similar to that observed at 3 years 6 months. There is, however, some evidence of progress. Firstly, Dylan at 3 years 11 months sustains the sorting by colour first observed five months earlier. Secondly, there is an increase in the number of contexts in which Dylan groups play materials by colour, from one to two.

4 years 2 months

At 4 years 2 months, assessment data again shows Dylan sustaining sorting by colour, but this time in the new context of Bead Threading. Additionally, Dylan, as previously, uses a similarity group when 'marking the centre' of the pegboard.

4 years 7 months

The examples below represent Dylan's most complex work at this age, in terms of the observed features of colour organisation.

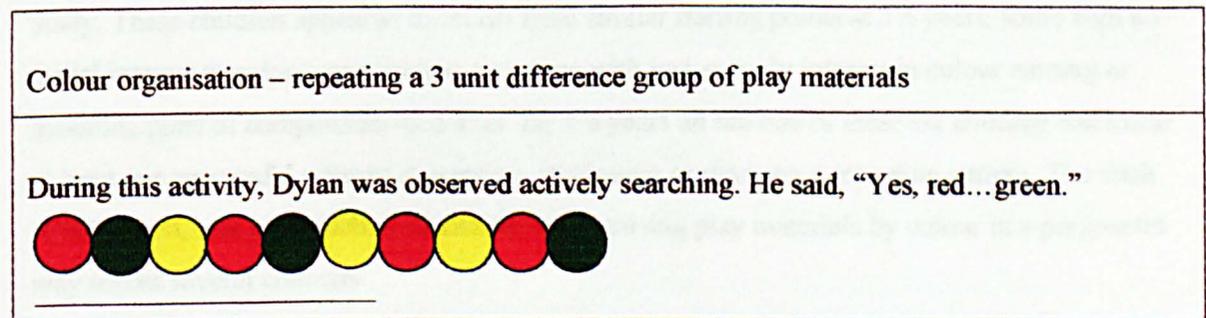


Figure 6.32 Dylan: Teddy's Beads 4 at 4 years 7 months

In the work above, Dylan repeats the 3 unit difference group once and then continues to alternate units of the play materials.

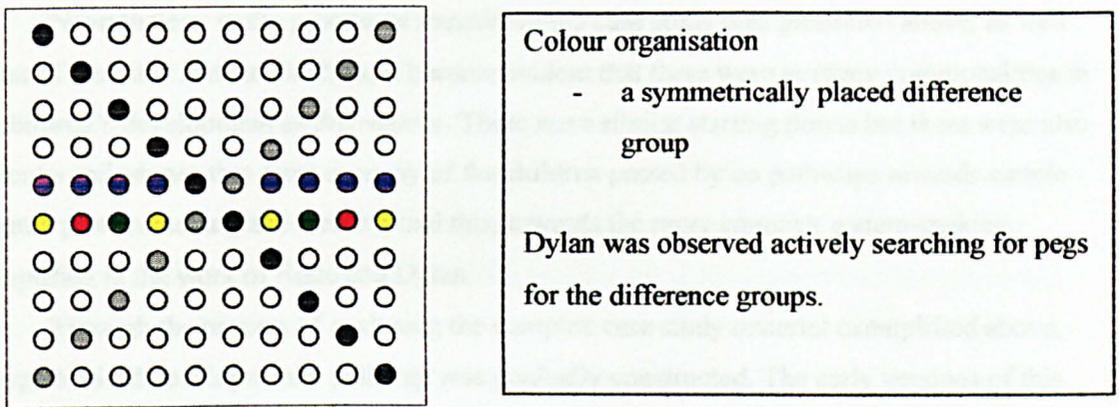


Figure 6.33 Dylan: Pegs and Pegboard at 4 years 7 months

At 4 years 7 months, Dylan also made 2 unit repeating patterns in a number of different contexts. In *Teddy's Beads 1*, he successfully copied the repeating pattern and in *Teddy's Beads 2* he successfully continued this pattern. In *Teddy's Beads 3*, Dylan devised a pattern with blue and orange beads. Finally, Dylan copied a repeating pattern in *Mosaics 2*.

Between 3 years 6 months and 4 years 7 months, there is evidence of Dylan making significant progress in the colour organisation strand of pattern-making, moving on from simple to more complex forms of colour organisation. There is also evidence of progression in terms of Dylan's use of forms of colour organisation in an increased range of contexts.

Dylan demonstrated positive dispositions for learning across most areas of the curriculum throughout the study. However, he remained reluctant to engage in mark-making activities at the end of the study.

Discussion

The six children, whose work has been presented and analysed in the section above, made considerable progress towards and within repeated pattern-making over the year of the study. These children appeared to set off from similar starting points at 3½ years, some with no initial interest in colour organisation and some with just an early interest in colour naming or grouping pairs of components by colour. By 4½ years all but one of these six children had made at least one successful attempt at copying, continuing or devising a repeating pattern. The sixth child, Aaron, was nevertheless successful in organising play materials by colour in a purposeful way across several contexts.

Despite apparently similar starting points, there does appear to be wide variation in the rate at which these children, as well as the other children in the longitudinal study, developed. There is also wide variation in the complexity and the diversity of their pattern-making work at 4½ years. Related to this, there appears to be variation in the children's creativity in pattern-making, in the extent to which they explored pattern-making beyond the templates of repeated patterns provided for them during the study.

Nevertheless, in the process of examining the case study data presented above, as well as that of the other sixteen children, it became evident that there were as many commonalities in the children's development as differences. There were similar starting points but there were also particular milestones that most or many of the children passed by on pathways towards simple repeated pattern-making and then beyond this, towards the more complex pattern-making exemplified in the work of Rona and Dylan.

Through the process of analysing the complex case study material exemplified above, an hypothesised developmental pathway was gradually constructed. The early versions of this pathway were repeatedly checked back against the data until a developmental pathway that best matched the data had been constructed.

TOWARDS REPEATING PATTERNS: AN HYPOTHESISED PATHWAY

The hypothesised pathway towards repeating pattern-making, arising from the process described above, is outlined below. It is exemplified in Appendix 5. The pathway leads towards complex repeated pattern-making through seven hierarchically ordered levels of colour organisation. The hypothesised pathway is tentative in relation to the two highest levels because in this sample few children worked at these levels.

One or two descriptors are presented for each level of the hypothesised pathway. Where there are two descriptors at a level, the initial descriptor relates to children's linear work and the second descriptor relates to 2D work in the Pegs and Pegboard activity.

Table 6.1 Hypothesised developmental pathway to complex colour organisation

Level	Descriptors
1	<ul style="list-style-type: none"> • no evidence of colour organisation
2	<ul style="list-style-type: none"> • colour naming
3	<ul style="list-style-type: none"> • colour grouping based on relationships of similarity or difference
4	<ul style="list-style-type: none"> • colour sequencing based on relationships of similarity and difference • 2D colour grouping based on relationships of similarity
5	<ul style="list-style-type: none"> • linear repeated pattern-making • 2D colour sequencing based on relationships of similarity and difference
6	<ul style="list-style-type: none"> • complex linear repeated pattern-making (3+ units) • complex 2D colour sequencing based on relationships of similarity and difference
7	<ul style="list-style-type: none"> • 2D repeated pattern-making

TOWARDS REPEATING PATTERNS: NUMERICAL AND QUANTITATIVE DATA

The hypothesised developmental pathway towards complex repeated pattern-making, was distilled from the analysis of case study data, including the six case studies presented above. Its presentation was supported by logical argument. This hypothesised pathway was then evaluated through an examination of numerical data and through quantitative data analysis.

Any hypothesised developmental pathway is based on the assumption that generally, over time, children will make progress. There is a built in expectation that this progress can be evidenced through children's work at increasingly advanced levels over time. Numerical and quantitative data analysis has been carried out to examine the nature and extent of children's progress through the levels of the hypothesised pathway over the year of the study. Progress of other kinds, relating to the colour organisation strand of pattern-making, has also been quantified.

The results of this analysis do need to be treated with some caution, however. Children's progress can only be assessed using the levels of the hypothesised pathway and there is no external system of measurement that can be used to validate the pathway.

In the section that follows, numerical and quantitative data from four assessment contexts is presented:

1. Bead Threading
2. Teddy's Beads
3. Mosaic Tiles
4. Pegs and Pegboard

It represents children's work with three different kinds of play materials, beads, pegs and mosaic tiles.

Numerical Data: Progression Through Colour Organization Levels

In the section that follows, numerical data is presented, relating to children's progression through colour organisation levels. An analysis was undertaken of colour organisation data from the 24 children in the longitudinal study. Each child was assigned a level, from 1 to 7, corresponding to his or her most advanced work at 3½ and 4½ years. Children's levels at age 3½ are reported as Assessment 1. Levels at age 4½ are reported as Assessment 4. Levels from intermediate assessment data, from a restricted sub-set of assessments, are also reported. These are reported as Assessment 2 and Assessment 3.

Table 6.2 Children's progression through colour organization levels

No = 24				
Child	Assessment 1	Assessment 2	Assessment 3	Assessment 4
A	4 L	4 L	4 L	5 L
B	1 L 2D	3 L	3 L	4 L
C	3 L	1 L 2D	5 L	5 L 2D
D	1 L 2D	1 L 2D	1 L 2D	4 L
E	1 L 2D	5 L	4 L 2D	5 L
F	4 L	5 L	5 L	6 L
G	5 L	4 L	1 L 2D	6 L
H	4 L	3 2D	5 L 2D	5 L
I	3 L	5 L	5 L	7 2D
J	1 L 2D	3 L	1 L 2D	4 L
K	1 L 2D	1 L 2D	4 L	5 L
L	6 2D	4 L	5 L	6 2D
M	5 L	5 L	5 L	5 L <i>r s</i>
N	3 2D	2 L	5 L	4 L
O	5 L	5 L	5 L	5 L <i>n</i>
P	5 L	5 L	5 L	6 L
Q	3 L	4 L	5 L	4 L 2D
R	2 L	4 L	5 L 2D	5 L
S	5 L	3 L	4 L	3 L
T	1 L 2D	1 L 2D	1 L 2D	1 L 2D
U	5 L	4 L	5 L	6 L
V	3 L	3 L 2D	3 L	6 L
W	4 2D	6 2D	5 L 2D	5 L
X	2L	1 L 2D	4 L	4 L

Coding

L – Linear work *2D* – Pegs and Pegboard work

Assessment 4

n - the child works at the same level but in a new context

r - the child works at the same level but in but in an increased range of contexts

s - the child works at the same level but progresses to sustained working

Table 6.3 Summary of children's progression through colour organisation levels – Assessments 1 and 4

No = 24			
Children moving up levels – comparison of Assessment 1 and Assessment 4	79.1%	+1 level	33.3%
		+2 levels	12.5%
		+3 levels	20.8%
		+4 levels	12.5%
Children working at the same level – comparison of Assessments 1 and 4	16.7%		
Children working at the same level, but evidencing progress in terms of <ul style="list-style-type: none"> • a wider range of contexts • sustained working 	4.2%		
Children working at the same level, but evidencing progress in terms of a new context	4.2%		
Children regressing through colour organisation levels – comparison of Assessment 1 and Assessment 4	4.2%	-2 levels	

Table 6.4 Summary of children's progression through colour organisation levels – Assessments 1,2,3 and 4

No = 24			
Children making progress through levels without regression	37.5%	+1 level in all	8.3%
		+2 levels in all	4.2%
		+3 levels in all	16.7%
		+4 levels in all	8.3%
Children making overall progress but regressing in 1+ intermediate assessments from previous level	41.7%	Regression at Assessment 2 only	16.7%
		Regression at Assessment 3 only	8.3%
		Regression at assessment 4 only	4.2%
		Regression in two assessments	12.5%
Children working at the same level in all assessments	12.5%	Level 1	4.2%
		Level 5	8.3%
Children working at the same level In Assessments 1 and 4 but regressing in intermediate assessments	4.2%		
Children regressing overall	4.2%		

Table 6.5 Context of most advanced work

No = 24			
	Linear	2D	Linear and 2D
3½ years	62.5%	12.5%	25%
4½ years	79.2%	8.3%	12.5%

Summary

A comparison of assessment data at Assessment 1 (3½ years) and Assessment 4 (4½ years) shows that a majority of children made progress during the year of the study in terms of the hypothesised levels of colour organisation. The progress children made varied from an increase of one level to an increase of 4 levels. One group, 33.3% of children, demonstrated an increase of one level only. However, a group of similar size, 33.3% of children, demonstrated an increase of three or four levels.

One child only regressed in terms of demonstrated colour organisation levels between Assessment 1 and Assessment 4. Another child remained at level 1 throughout assessment periods, evidencing no progression in the colour organisation strand of pattern-making. Two of the three children who worked at the same level across assessments evidenced progression in

other ways. Although making overall progress between 3½ and 4½ years, the majority of children demonstrated uneven progress through the levels of colour organisation between assessment periods.

A majority of those children who demonstrated progress over the year without regression were amongst the group who made the greatest overall progress over the year of the study, progressing through three or four levels of colour organisation. The majority of children at both ages demonstrated their highest level of colour organisation in linear work, rather than in 2D work.

Discussion

This analysis of numerical colour organisation data from the 24 children in the longitudinal study provides some support for the hypothesised developmental pathway, exemplified above. The framework of seven hierarchically ordered levels of colour organisation allows for the identification of children's progress, from their early development in colour organisation, towards the development of knowledge, understanding and skills in complex repeated pattern-making.

In particular, the analysis of numerical data provides some support for the hypothesised pathway for linear work. There are difficulties, however, in evaluating the hypothesised pathway as it relates to children's 2D work. This is because relatively few children focused on colour organisation during the Pegs and Pegboard assessment. Later in the chapter, analysis and discussion highlights children's knowledge, understanding and skills in terms of spatial organisation. Spatial organisation, but not 2D colour organisation, was most often the focus of children's work with pegs, at both 3½ and 4½ years.

It is possible that the pathways followed by individual children are more distinctive than any generalised pathway will allow. Numerical data, using the framework of the hypothesised pathway, highlight uneven development for many children over the period of the study. Children sometimes regressed between assessment periods or remained at a particular level, in terms of hierarchically ordered levels of colour organisation. At the same time, there were other ways in which some children evidenced progress. For example, the analysis of numerical data has highlighted children who developed skills by working at a particular level in a new context or in an increased range of contexts. Sustained working has also been highlighted as a feature of development. For some children regression at particular points in time may have been a consequence of the restricted range of assessments carried out during assessment periods 2 and 3.

Exploratory Data Analysis: Boxplots

To take forward the evaluation of the hypothesised developmental pathway towards complex colour organisation, an exploratory data analysis technique was used. Boxplots were

used to explore the distribution of the levels of colour organisation achieved by the 24 children in the longitudinal study over time. The 24 children were assigned levels for work undertaken in three of the four assessment contexts at four assessment periods. The assessment periods were at 3½ and 4½ years, as well as at two intermediate points. Over the four assessment periods, children's ages ranged from 42 to 56 months.

A boxplot for each level of the hypothesised sequence provides a graphical representation of the dispersion of ages for children working at this level. Each boxplot shows the median age for children working at a level, the middle 50% of observations, as well as the highest and lowest ages. Outliers, the extreme cases beyond this, are also indicated.

Charts showing sequences of box plots for Bead Threading, Mosaic Tiles and Pegs and Pegboards assessment activities are presented below.

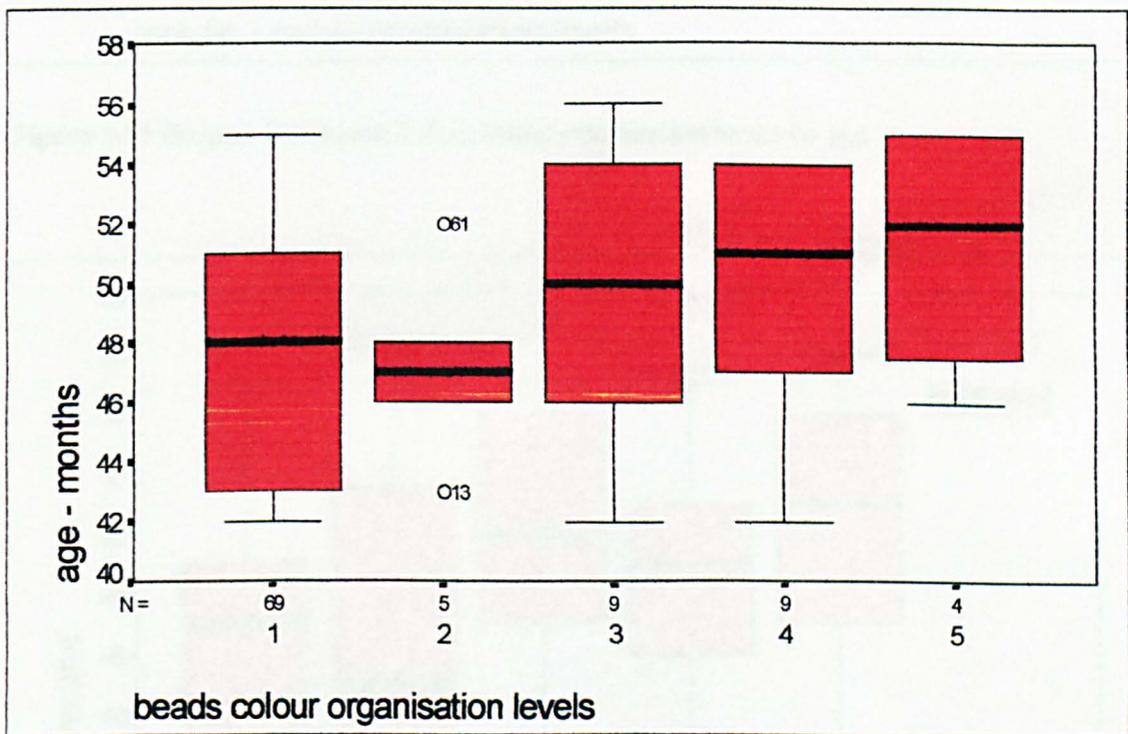


Figure 6.34 Boxplot for Bead Threading colour organisation levels by age

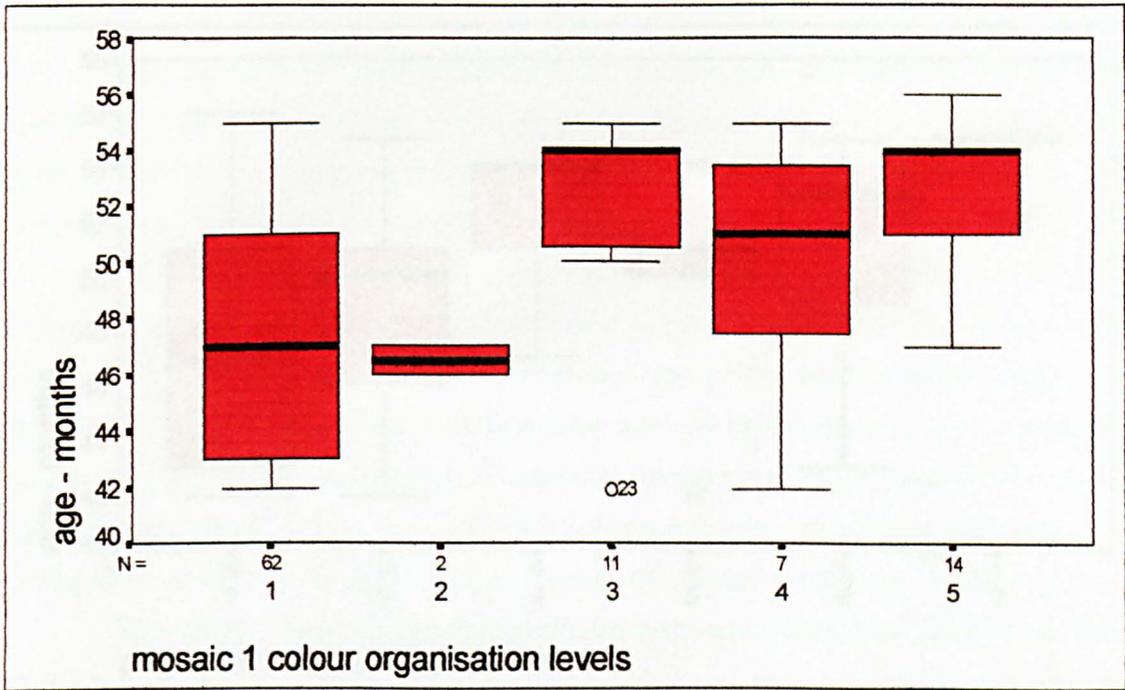


Figure 6.35 Boxplot for Mosaic Tiles 1 colour organisation levels by age

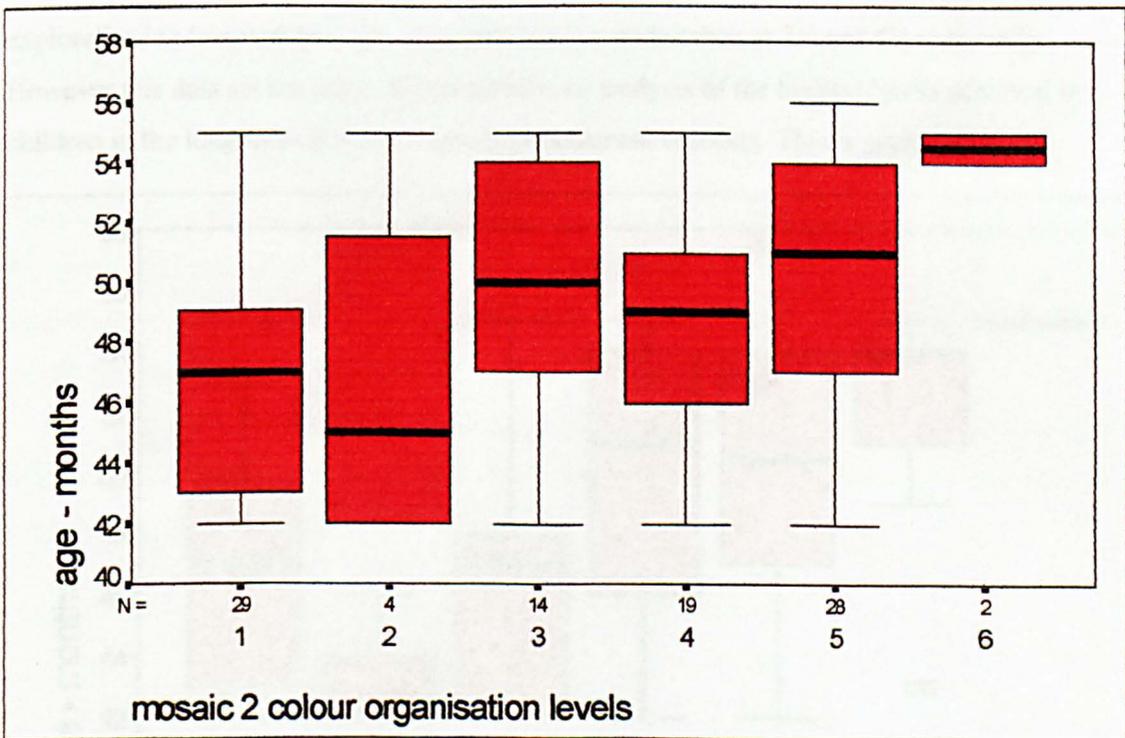


Figure 6.36 Boxplot for Mosaic Tiles 2 colour organisation levels by age

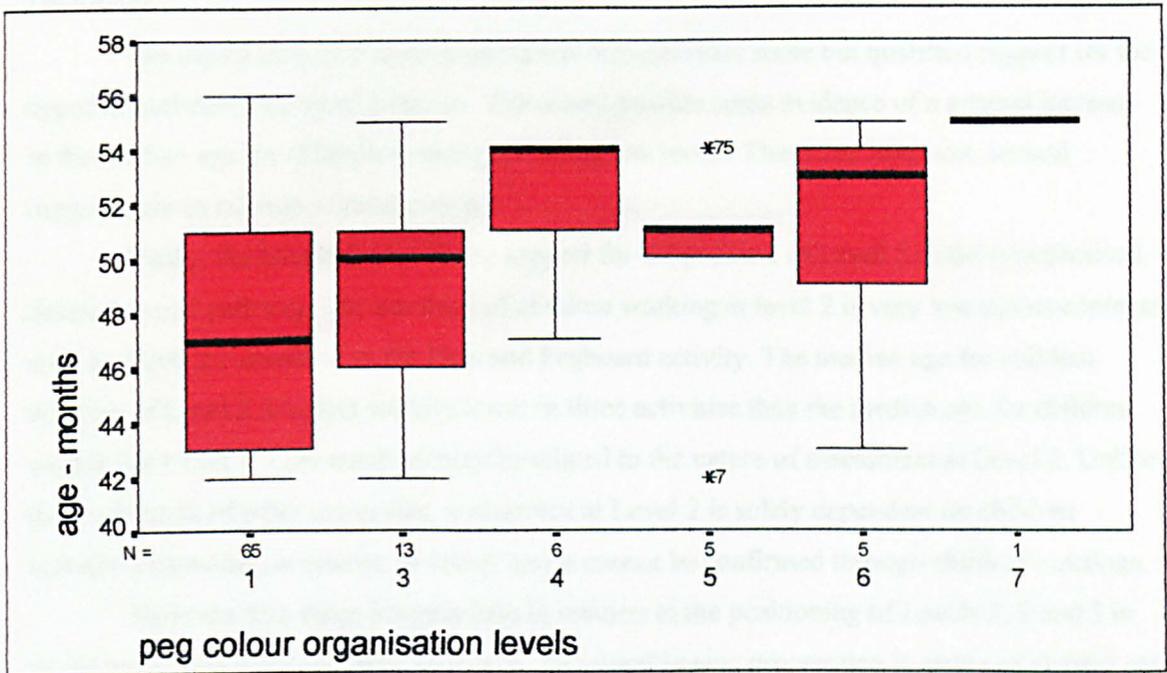


Figure 6.37 Boxplot for Pegs and Pegboard colour organisation levels by age

Colour organisation data from the Teddy's Beads assessment activities have not been explored using boxplots because assessments were undertaken at 3½ and 4½ years only. However this data set has been incorporated in an analysis of the highest levels achieved by children in the longitudinal study across all assessment contexts. This is presented below.

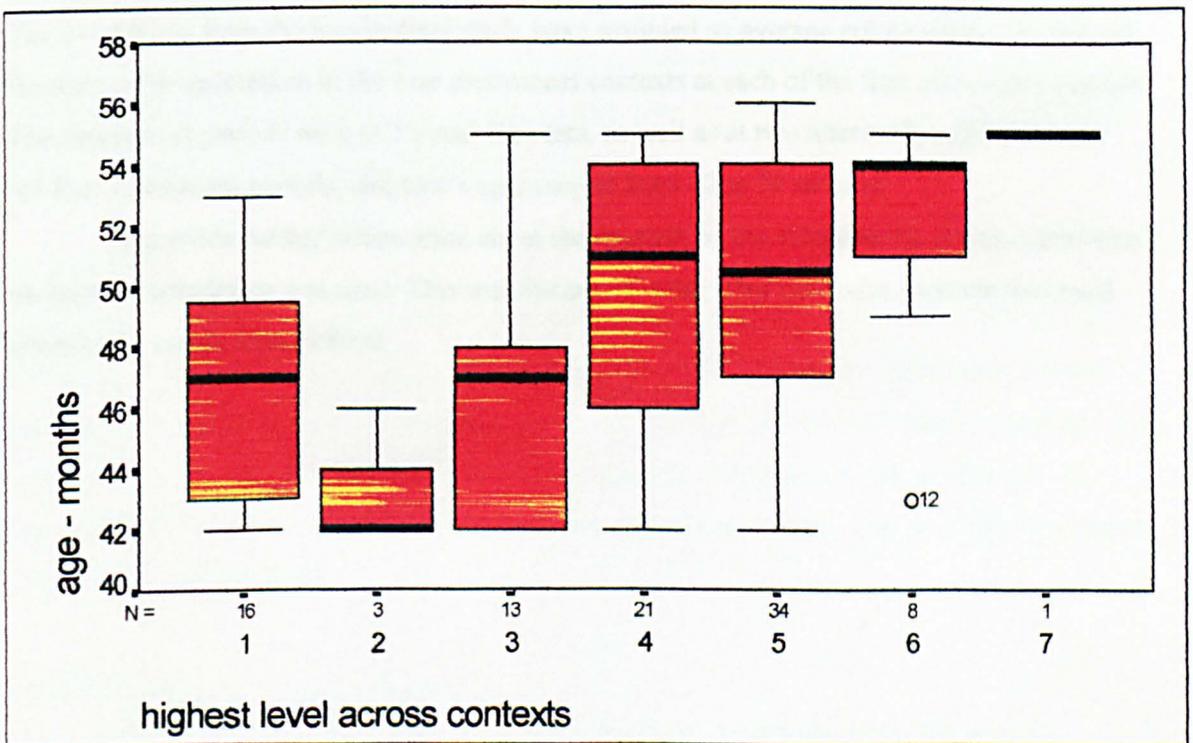


Figure 6.38 Boxplot for the highest colour organisation levels across contexts by age

Discussion

The exploration of colour organisation data provides some but qualified support for the hypothesised developmental pathway. The charts provide some evidence of a general increase in the median age for children working at the highest levels. There are, however, several irregularities in relation to progression.

Firstly, the boxplots provide no support for the position of Level 2 in the hypothesised developmental pathway. The numbers of children working at level 2 is very low across contexts, with no Level 2s identified in the Pegs and Pegboard activity. The median age for children working at Level 2 is in fact slightly lower in three activities than the median age for children working at Level 1. Low numbers may be related to the nature of assessment at Level 2. Unlike the assessment of other categories, assessment at Level 2 is solely dependent on children verbally expressing an interest in colour and it cannot be confirmed through children's actions.

There are also some irregularities in relation to the positioning of Levels 3, 4 and 5 in the hypothesised developmental sequence. An unambiguous progression in terms of median age is shown only for the Bead Threading activity. However, the median ages for children working at levels 3, 4 and 5 are very close across all contexts. There is no consistent pattern to the relative positioning of the median ages for children working at levels 3,4, and 5 across contexts.

Exploratory Data Analysis: A Scatter Diagram and Measure of Correlation

Additionally, a scatter diagram and a measure of rank correlation were used to explore the relationship between children's age and their demonstrated levels of colour organisation. The 24 children from the longitudinal study were assigned an average colour organisation level for their work undertaken in the four assessment contexts at each of the four assessment periods. The assessment periods were at 3½ and 4½ years, as well as at two intermediate points. Over the four assessment periods, children's ages ranged from 42 to 56 months.

To provide further information about the strength of this relationship, a rank correlation measure of correlation was used. This was Spearman's rho. This particular measure was used because the scores were ordinal.

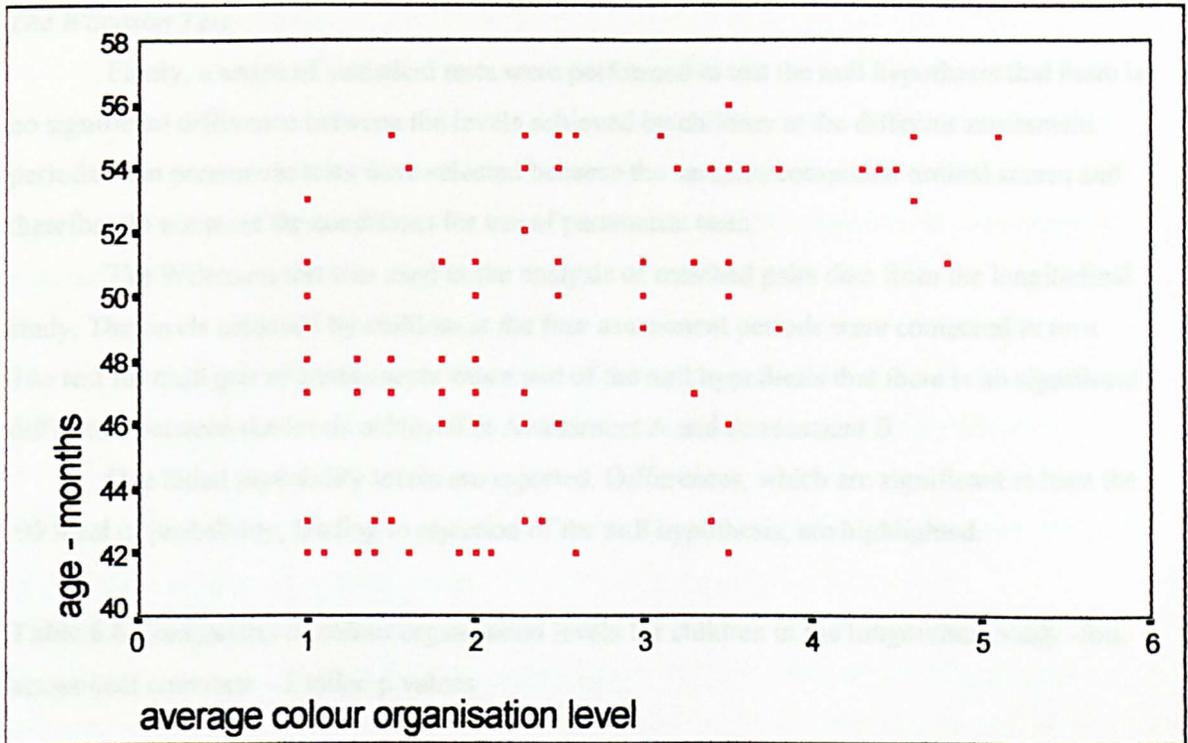


Figure 6.39 Scatter Diagram – average colour organisation score by age

The Scatter Diagram shows a weak positive relationship between the two variables, age and average colour organisation level.

From the results of the correlation carried out on the age of the children and their average colour organisation level, a significant positive association was found ($\rho = 0.4624$, $N = 24$, $p = 0.000$). It was concluded that, as children's age increases between 3½ and 4½ years, there is an increase in their average colour organisation levels.

Discussion

Quantitative analysis demonstrates a modest but significant correlation between age and children's average colour organisation levels. This analysis provides additional evidence, supporting the hypothesised developmental pathway, through the levels of colour organisation, towards complex pattern-making. A number of variables, in addition to age are likely to be associated with children's progress through colour organisation levels, and so a high correlation would be an unlikely result.

Statistical Data

Finally, statistical tests were performed on colour organisation data. These were undertaken to assess whether significant progress through the levels of the hypothesised pathway could be evidenced in the work of children at 4½ years, as compared to children at 3½ years, as well as at time intervals between these ages.

The Wilcoxon Test

Firstly, a series of statistical tests were performed to test the null hypothesis that there is no significant difference between the levels achieved by children at the different assessment periods. Non parametric tests were selected because the samples comprised ordinal scores and therefore do not meet the conditions for use of parametric tests.

The Wilcoxon test was used in the analysis of matched pairs data from the longitudinal study. The levels achieved by children at the four assessment periods were compared in turn. The test for each pair of assessments was a test of the null hypothesis that there is no significant difference between the levels achieved at Assessment A and Assessment B.

One tailed probability levels are reported. Differences, which are significant at least the .05 level of probability, leading to rejection of the null hypothesis, are highlighted.

Table 6.6 Comparison of colour organisation levels for children in the longitudinal study -four assessment contexts – 1 tailed p values

No = 23 Assessment Period 3 - Mosaic Tiles 1 and 2; Assessment Period 4 - Pegs and Pegboard				
No = 24 All other assessments				
Assessment Period	Bead Threading	Mosaic Tiles 1	Mosaic Tiles 2	Pegs and Pegboard
1 and 2	.246	.101	.067	.216
1 and 3	.145	.012	.004	.195
1 and 4	.139	.000	.001	.014
2 and 3	.264	.025	.019	.056
2 and 4	.357	.000	.006	.005
3 and 4	.464	.002	.398	.098

Table 6.7 Comparison of colour organisation levels for children in the longitudinal study – Teddy's Bead's assessment contexts – 1 tailed p values

No = 22 Assessment Period 1- Teddy's Beads 3 and 4				
No = 24 All other assessments				
Assessment Periods	Teddy's Beads 1	Teddy's Beads 2	Teddy's Beads 3	Teddy's Beads 4
1 and 4	.000	.000	.003	.006

The Mann-Whitney U Test

The Mann-Whitney U test was used in the analysis of data from the larger unrelated samples. The levels achieved by children at the assessment periods, for children at 3½ and 4½ years were compared in turn. The test for each pair of assessments was a test of the null hypothesis that there is no significant difference between the levels achieved at Assessment 1 and Assessment 2.

One tailed probability levels are reported. Differences, which are significant at at least the .05 level of probability, leading to rejection of the null hypothesis, are highlighted.

Table 6.8 Comparison of colour organisation levels for children in the cross-sectional study – 8 assessment contexts – 1 tailed p values

Assessment Periods 1 and 4	U	1- Tailed p
Bead Threading	957.0	.012
Mosaic Tiles 1	622.0	.000
Mosaic Tiles 2	597.5	.000
Pegs and Pegboard	892.0	.007
Teddy's Beads 1	570.5	.000
Teddy's Beads 2	570.5	.000
Teddy's Beads 3	722	.000
Teddy's Beads 4	770.5	.000

Discussion

In a comparison of the levels at which children worked at 3½ and 4½ years in the longitudinal study, the null hypothesis can be rejected for seven of the eight assessment contexts. In a similar comparison of children's levels in the larger unrelated samples, the null hypothesis can be rejected for all assessment contexts. Using assessment levels from the hypothesised developmental pathway for colour organisation, the results demonstrate a significant difference between children's achievement at 3½ and 4½ years. These results provide some support for the broad outlines of the hypothesised developmental pathway.

However, the tests of progress taking account of the two additional assessment periods for the children in the longitudinal study are of greater importance to a consideration of the hypothesised developmental pathway. Progress for children in the longitudinal study in the three or four months between assessment periods is likely to be less than progress between 3½ and 4½ years. Evidence of significant progress within a 3 or 4 month period or within a 5 to 7 month period is likely to indicate children moving up a single level, rather than up several levels.

There is in fact some but limited evidence of children making significant progress through the hypothesised levels within the shorter time periods, although not for children at the

earliest age. In a comparison of the levels for children working at Assessment 1 and Assessment 2, it is not possible to reject the null hypothesis in any of the four assessment contexts. Across contexts, there appear to be no significant differences between children's performance during the first assessment period, at 3½ years, and their performance during the subsequent period.

In a comparison of the levels for children working at Assessments 2 and Assessment 3, the null hypothesis can be rejected for two assessment contexts but it cannot be rejected for the other two contexts. In both the contexts in which children work with mosaic tiles there is evidence of significant progress through the hypothesised levels of the developmental pathway.

In a comparison of the levels for children working at Assessment 3 and Assessment 4, the null hypothesis can be rejected for one assessment context but not for the other three. There is evidence of children making significant progress through the levels of the hypothesised developmental pathway in just one of the four contexts, Mosaic Tiles 1.

There is more conclusive evidence that children make significant progress through the levels of the hypothesised developmental pathway between three assessment periods than between two assessment periods. In a comparison of the levels for children working at Assessment 1 and Assessment 3, and a comparison of the levels for children working at Assessment 2 and Assessment 4, the null hypothesis can be rejected for six out of eight assessment contexts. There is evidence that children make significant progress through the hypothesised levels of the developmental pathway in their work with mosaic tiles and in their work with pegs, both between Assessment 1 and 3, and between Assessments 2 and 4.

Although the boxplot for Bead Threading appears to give greater support to the hypothesised developmental pathway than boxplots relating to other assessment contexts, the statistical analysis provides no significant results relating to children's progress through hypothesised levels for Bead Threading. This is likely to be a consequence of the relatively high numbers of children working at Level 1 in Bead Threading at all assessment periods. Two explanations could account for children's relatively low performance levels in this assessment context. Firstly, no adult scaffolding supported pattern-making activity in the Bead Threading context. Secondly, in the absence of adult scaffolding the play materials seemed to encourage children to focus attention on the numbers of beads or the length of necklaces rather than on colour organisation.

In conclusion, the quantitative analysis provides a range of evidence supporting the hypothesised developmental pathway within the colour organisation strand of pattern-making. The support however is qualified. In particular, there is insufficient evidence to support the position of Level 2 as a distinct level within the sequence. In evaluating the developmental pathway, it is also important to note the small numbers of children in the sample using colour organisation in 2D work and, in particular, the small numbers of children working at levels 6 and 7.

TOWARDS REPEATING PATTERNS: WITHIN LEVEL DEVELOPMENT

The analysis of numerical data above highlighted a group of children, 16.7% of the sample, making no progress through the levels of the hypothesised developmental pathway towards complex colour organisation over the year. Analysis highlighted a further child, who appeared to regress in terms of colour organisation levels.

This group of children may support identification of features of within level development not included in the developmental pathway. The levels of the hypothesised developmental pathway feature solely as stepping stones along the main route to complex colour organisation. They do not encapsulate all aspects of children's development within the colour organisation strand of pattern-making. Numerical analysis, as well as the case studies above, has identified aspects of development taking place within levels. These aspects of development are examined below.

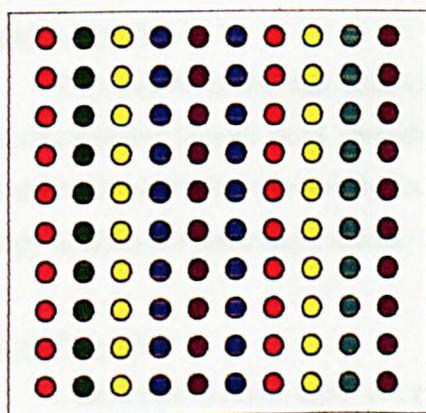
The group of children identified above also presents evidence disconfirming the hypothesised pathway towards complex colour organisation. An examination of individual cases from this group may support identification of categories of colour organisation wrongly leveled in the developmental sequence.

To support the further examination of within level development and the identification of wrongly leveled categories, a seventh case study is presented. This is the case study of Christopher, one of the children who appeared to make no progress through the levels of the hypothesised pathway over the year.

Christopher

3 years 7 months

By the time of the first assessments, Christopher had settled happily at nursery and was confident to participate in a wide range of activities. The example below represents the highest level of colour organisation observed at this age. It also represents the highest level of working, in terms of colour organisation, in the longitudinal study for all children at 3½ years.



Level 6 colour organisation

- a chained difference series of line units

Christopher said, "different colours," as he picked up yellow pegs for the third row.

Figure 6.40 Christopher: Pegs and Pegboard at 3 years 7 months

At this age, Christopher also demonstrated Level 4 colour organisation, ‘alternating similarity groups and units,’ in four contexts. In three contexts he used the colours used in the model or modeled patterns. In the fourth context, Teddy’s Beads 4, he used the colours named in the invitation to make a pattern.

Level 4 colour organisation – alternated similarity groups and units (a)



Figure 6.41 Christopher: Teddy’s Beads 2 at 3 years 7 months

Additionally at this age, Christopher made a difference group, in Teddy’s Beads 3, saying, “I do different colours on it.” He was observed checking back to his threading to confirm which colours had been used already. He did not, however, use all available colours, as in the difference series made with pegs.

3 years 10 months

At this age, Level 4 colour organisation was again the highest level of colour organisation demonstrated. Christopher placed ‘alternated similarity groups and units’ in Mosaic Tiles 2. He devised a ‘difference series,’ in Bead Threading, saying, “I want to put different colours on.”

During this assessment period, Christopher, working independently with chalks and a chalkboard, devised a further and unusual difference series. He drew a sequence of vertical lines, using each available colour of chalk in turn and said, “It’s only colours, patterns of a flower.”

4 years 1 month

Christopher, at this age, used Level 5 colour organisation for the first time, devising repeating patterns in both Bead Threading and Mosaic1. There is evidence of progression here, in that Christopher’s had previously used Level 4 colour organisation in response to invitations to copy or continue repeating patterns.

4 years 7 months

Christopher worked again at Level 6 during this assessment period, devising a ‘difference series of line-units.’ In other assessments, he continued working at Levels 3, 4 and 5.

Progression, at this age, can be seen in the increased fluency of his devising work, using new colour combinations for devised patterns in *Bead Threading* and *Mosaic 1*.

Christopher showed a continuing preoccupation with the use of different colours. He devised a single difference series in *Pegs and Pegboard*, and a difference group in *Teddy's Beads 3*, again saying, "I'll do different colours."

There is evidence of progression over the year as Christopher developed skills in copying, continuing and devising repeating patterns in an increasing range of contexts. At 3 years 7 months, he worked at Level 6 in one activity, Level 4 in four activities, Level 3 in one activity and Level 1 in two activities. At 4 years 7 months, although Level 6 was again the highest level of working, Christopher had progressed to Level 5 working in four activities, while working at Levels 3 and 4 in the remaining activities.

Over the year Christopher also showed a strong preoccupation with the idea of 'different colours,' as a key feature of his developing concept of pattern. He continually returned to this idea in his work with pattern-making materials.

Discussion

Other children in the study did not seem to share Christopher's preoccupation with different colours. The case study above highlights the need to be alert to individual differences in development when proposing any generalised pathway of development. It also highlights and provides evidence relating to within-level developments.

During the study, only a minority of children moved steadily through the levels, with an increase in performance at each assessment period. In addition, although most children, unlike Christopher, progressed through one or more levels of colour organisation over the year, performance within each assessment period was variable, often highly variable. As children progressed through the higher levels of colour organisation, they continued to work at lower levels at particular times or in particular contexts. Considering the case studies presented to date, with one exception, those children who progressed to a new and higher level of colour organisation, during an assessment period, first worked at this level in just one or two contexts. Often those children, who remained at a level or regressed to an earlier level of working, continued to make progress in other important ways. For example, development often took place as children, like Christopher at 3 years 10 months, extended the range of contexts for working within a level. Secondly, development within a particular level often took place as children learned to work in more sustained ways. Thirdly, development sometimes took place as children progressed from copying a model or modeled patterns to devising their own sequences or patterns.

It is important to note that, although devising often follows copying, particularly at Level 5, the route of development, from copying to devising, is not invariable. At this and earlier stages, children seem to vary in terms of their motivation to devise sequences and

patterns, with motivation not directly related to the level at which children are working. Some children, from early on, for example Andrew, are strongly motivated to work with a favourite colour or to devise a colour sequence using colours that are different to the modeled sequence. Additionally, Christopher, with his preoccupation with devising sequences of “all different colours,” provides an example of a child motivated to explore a particular theme in a self-directed way, rather than to follow the direction of the adult. Initially, Christopher worked at a higher level in devising than in copying or continuing work.

In conclusion, while there is qualitative and quantitative evidence to support key aspects of a hypothesised pathway towards advanced levels of colour organisation, particularly in terms of children’s linear work, children progress along this pathway in highly individual ways.

Christopher’s case study also highlights the problematic nature of the hypothesised pathway in relation to children’s 2D work. The limited data set relating to 2D work has led to difficulties in placing this work alongside linear work in the developmental sequence. Christopher undertook 2D patterning, at 3 years 7 months, some time before establishing skills in linear repeated pattern-making. Christopher’s work, may be an example of the “flashes of over-achievement” noted by Meadows (1993). Alternatively the 2D pattern-making, demonstrated by Christopher at 3 years 7 months, may have been inappropriately placed in the developmental sequence.

At this point it is important to turn from colour organisation to the evidence concerning the second major area of children’s developing knowledge, understanding and skills in pattern-making, spatial organisation. Knowledge, understanding and skills relating to colour and spatial organisation develop concurrently. It is possible that some children stand still or backtrack on one pathway because attention is, for a time, focused on another pathway.

SPATIAL PATTERNS: DEVELOPMENT BETWEEN THE AGES OF 3½ AND 4½ YEARS

The second research question asks:

2. Where do knowledge understanding and skills in pattern-making begin and how do they develop between the ages of 3½ and 4½ years?

To answer this question and the related third and fourth research questions in terms of children’s knowledge, understanding and skills in spatial pattern-making, it is necessary to focus again on two key aspects of development. Firstly, it is necessary to focus on the earliest stages of young children’s developing knowledge, understanding and skills in the spatial organisation of play materials. In following this direction, it is again important to acknowledge that the early stages in the developmental process may look very different to later competencies.

Secondly, the research questions under consideration lead to a focus on identification of the stages between early competence in spatial organisation and the more advanced levels of spatial

pattern-making demonstrated by a very small group of children at 3½ and a significant minority of children at 4½ years.

In the section that follows these two aspects of development are considered in two ways. Firstly the qualitative data from assessment activities and from additional case study data are examined in order to illuminate the developmental pathways followed by children towards and within spatial pattern-making. Secondly, hypothesised pathways, arising from this analysis, are re-examined in the light of the quantitative data yielded by main study assessment activities. Statistical analysis is used to test key features of the hypothesised pathways.

TOWARDS SPATIAL PATTERNS: CASE STUDY DATA

A longitudinal study was set up to track the development towards pattern-making of a group of 24 children from 3½ to 4½ years of age. This group comprised:

- two children in low groups for both spatial and colour organisation – Aaron and Lauren
- one child in a medium group for both spatial and colour organisation – Andrew
- one child in a medium group for colour organisation - Gemma
- one child in a medium group for spatial organisation and a high group for colour organisation - Rona
- one child in a high group for spatial organisation - James
- one child in a high group for spatial organisation and a high group for colour organisation – Dylan

In this part of Chapter 6, aspects of children's development within the spatial organisation strand of pattern-making are examined in a detailed way. This is undertaken through the analysis of qualitative assessment data and additional case study material. Exemplification focuses on work with pegs. Additional reference is made to work with mosaic tiles.

Recording categories of spatial organisation:

- The placement of pegs has been recorded in shades of grey, except where colour organisation is a feature of the work.
- The proximity placement of pegs is recorded through the use of shades of grey.
- Where large parts of the pegboard are filled, proximity placement is recorded through the use of black lines.
- Non-linear basic elements, from the basic elements of symmetry, are recorded through the use of black.
- The multi-directional proximity placing of lines is recorded through the use of green lines.
- The symmetrical marking of lines is recorded with orange.
- The uni-directional proximity placing of lines is recorded through the use of red lines.

- Where children's pegboard work shows evidence of developing spatial organisation, their random placement of pegs is recorded but not included in the descriptions of key features.

Aaron

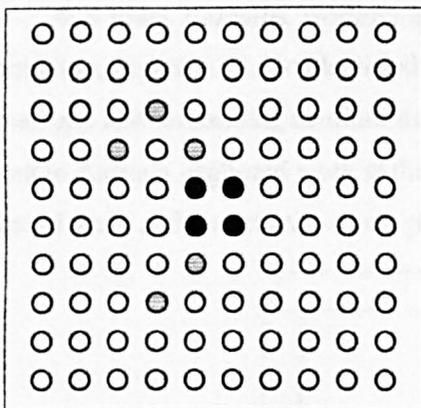
Aaron is representative of the low group for spatial organisation.

3 years 6 months

Aaron used unidirectional proximity placement to make a sustained line of mosaic tiles on a duplo strip in Mosaic Tiles 2. In work with pegs, Aaron placed pegs without evident spatial organisation. At this age, Aaron was uninterested in play with the pegs and stayed with the activity only briefly.

3 years 11 months

Aaron used unidirectional proximity placement to make a sustained line in Mosaic Tiles 1. He used unidirectional proximity placement to make a partial line in Mosaic Tiles 2.



In Figure 6.42, Aaron used:

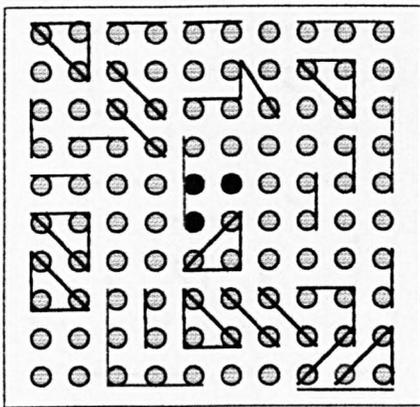
- linear organisation
 - proximity placement
- centre markings
 - marking the centre - sustained

Figure 6.42 Aaron's devised peg pattern at 3 years 11 months

Again, basic linear organisation is evident in Aaron's work with tiles but it is not yet secure across contexts. However, there is evidence of progression in Aaron's pegboard work, firstly in terms of the new use of proximity placement and secondly, in the new use of centre markings. By this age, Aaron was showing some interest in play with these materials

4 years 2 months

Aaron used unidirectional proximity placement to make a sustained line in Mosaic Tiles 1 and 2.



In Figure 6.43, Aaron used:

- linear organisation
 - proximity placement
 - multidirectional proximity placement
 - partial line
- centre markings
 - marking the centre - partial

Figure 6.43 Aaron's devised peg pattern at 4 years 2 months

Again, basic linear organisation is evident in Aaron's work with tiles but at 4 years 2 months, it is not secure across contexts. There is evidence of progression in pegboard work, in terms of Aaron's increased use of proximity placement and his new use of multidirectional proximity placement to make a partial line. Aaron set himself the objective of filling the complete pegboard but he began to tire towards the end of the activity, asking, "Have I finished?"

At 4 years 2 months, working independently with wooden blocks, Aaron made a 4 sided construction, Figure 6.44. He identified the construction as 'a house'. This work, in a different and perhaps less demanding medium than pegs, indicates more advanced spatial thinking than is evident in Aaron's pegboard work at this age. The work with blocks is a precursor of Aaron's pegboard work at the next assessment period.

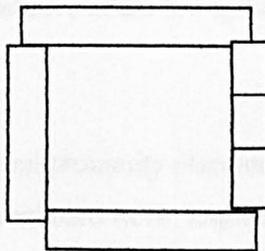


Figure 6.44 Aaron's work with blocks

4 years 6 months

Aaron used unidirectional proximity placement to make a sustained line in Mosaic Tiles 2. He regressed to use of multidirectional proximity placement to make a line in Mosaic Tiles 2. Regression may have resulted from Aaron's sustained focus on colour organisation in Mosaic Tiles 2.

4 years

Lauren used multidirectional proximity placement to make a sustained line of mosaic tiles in Mosaic Tiles 1 and unidirectional proximity placement to make a sustained line of mosaic tiles in Mosaic Tiles 2. There was no evidence of progress in pegboard work. Although Lauren demonstrated basic linear organisation at 4 years, this was not yet secure across contexts.

Lauren showed relatively low levels of engagement with the work with tiles and pegs. She chatted about home events as she placed tiles and pegs,

4 years 4 months

Lauren used multidirectional proximity placement to make a partial line in Mosaic Tiles 1. She used unidirectional proximity placement to make a sustained line in Mosaic Tiles 2.

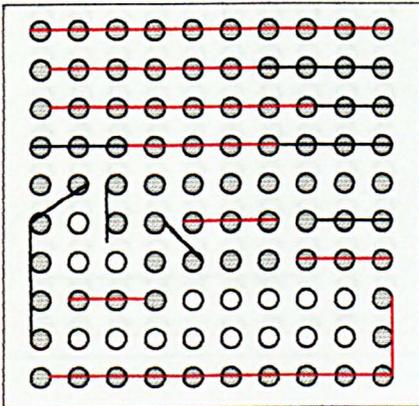


Figure 6.47 Lauren's devised peg pattern at 4 years 4 months

In Figure 6.47, Lauren used:

- linear organisation
 - proximity placement
 - multidirectional proximity placement – partial line
 - unidirectional proximity placement – partial line
 - 2+ lines repeated and connected - multidirectional proximity placement and partial lines
 - 2+ lines repeated - unidirectional proximity placement and sustained lines

There is evidence of a significant increase in the complexity of linear organisation in Lauren's pegboard work by the time of the third set of assessments, at age 4 years 4 months. Basic linear organisation is established in work with pegs. Peg lines are both connected and repeated.

4 years 6 months

There appears to be regression in the level of Lauren's work at 4 years 6 months. Lauren used multidirectional proximity placement to make a sustained line in Mosaic Tiles 1. She used multidirectional proximity placement to make a partial line in Mosaic Tiles 2. During the pegboard activity, Lauren expressed a lack of interest in continuing with the work after placing just one line of pegs.

Over the year, Lauren made significant progress in terms of development from the earliest levels of linear organisation into more complex linear organisation. However, she made no use of nonlinear basic elements of symmetry over the year. As stated previously, Lauren showed uneven levels of interest in assessment activities over the year and she was occasionally anxious to return to other activities.

Andrew

Andrew is representative of the medium group for spatial organisation

3 years 7 months

Andrew used multidirectional proximity placement to make sustained lines in Mosaic Tiles 1 and 2

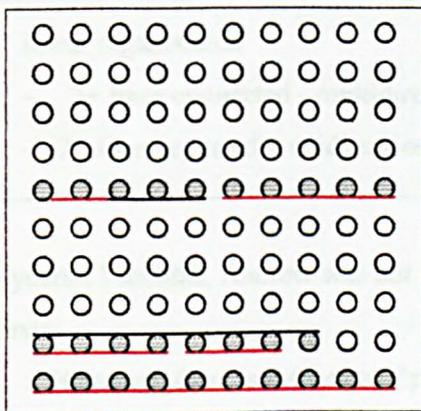


Figure 6.48 Andrew's devised peg pattern at 3 years 7 months

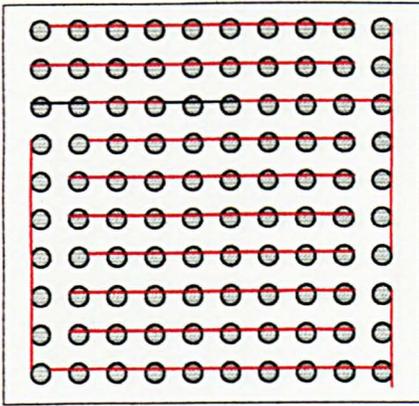
In Figure 6.48, Andrew used:

- linear organisation
 - multidirectional proximity placement – partial line
 - unidirectional proximity placement – partial line
 - unidirectional proximity placement – sustained line
 - 2+ lines repeated – multidirectional proximity placement and partial lines

At 3 years 6 months, Andrew used basic linear organisation in work with pegs but basic organisation was not secure across contexts.

3 years 11 months

Andrew used unidirectional proximity placement to make a partial line in Mosaic Tiles 1. He used multidirectional proximity placement to make a sustained line in Mosaic Tiles 2.



In Figure 6.49, Andrew used:

- linear organisation
 - multidirectional proximity placement – partial line
 - unidirectional proximity placement – partial line
 - unidirectional proximity placement – sustained line

Figure 6.49 Andrew's devised peg pattern at 3 years 11 months

Andrew also used:

- linear organisation
 - 2+ lines connected - multidirectional proximity placement and/or partial lines
 - 2+ lines repeated – unidirectional proximity and sustained lines

At 3 years 11 months, Andrew was not yet using basic linear organisation reliably across contexts.

However, there is evidence of progression in Andrew's pegboard work at this age as he makes increasing use of repeated lines and uses connected lines for the first time.

Andrew also shows a strong sense of engagement with pegboard work at this age, saying twice to the adult, "Look, look, like it's a house."

At 3 years 11 months, Andrew painted a pattern that relates spatially to the developments observed in his pegboard work. He painted a line along each of the edges of a square of card, and then filled much of the square with scribbled strokes.

4 years 3 months

At 4 years 3 months Andrew used unidirectional proximity placement to make sustained lines in Mosaic Tiles 1 and 2.

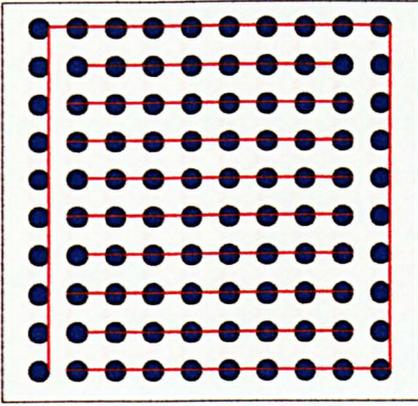


Figure 6.50 Andrew's devised peg pattern at 4 years 3 months

In Figure 6.50, Andrew made a spatial pattern. He used:

- linear organisation
 - 8 lines repeated – unidirectional proximity placement and sustained lines
 - 4+ lines connected – unidirectional proximity placement and sustained lines

By 4 years 3 months, basic linear organisation is reliably established. There is further progression towards complex spatial organisation. Additionally, Andrew has coordinated the use of two key configurations to create a symmetrical pattern. The pattern appears to be closely related to and developed from the less coordinated work at 3 years 11 months.

4 years 7 months

At this age Andrew again used unidirectional proximity placement to make sustained lines in Mosaic Tiles 1 and 2. Like Lauren at this age, however, Andrew in his pegboard work regressed to the use of less complex forms of spatial organisation.

During the year of the study, Andrew showed a particular interest in pegboard work and often self-initiated work alongside a cousin with similar interests.

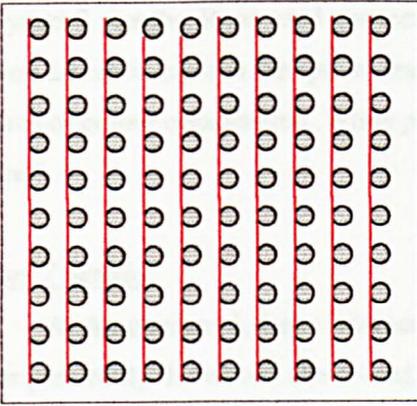
Rona

Rona is representative of the medium group for spatial organisation.

3 years 7 months

Rona showed a keen interest in work with tiles and pegs from the beginning of the year but with attention particularly focused on colour.

At 3 years 7 months, basic linear organisation, for Rona, was secure across contexts. She used unidirectional proximity placement to make sustained lines in Mosaic Tiles 1 and 2, as she continued to do throughout the four assessment periods.

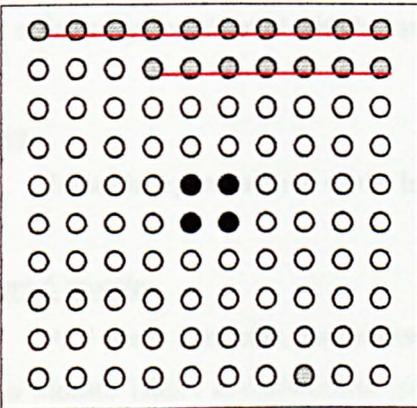


In Figure 6.51, Rona used:

- linear organisation
 - 10 lines repeated – unidirectional proximity placement and sustained lines

Figure 6.51 Rona's devised peg pattern at 3 years 7 months

4 years



In Figure 6.52, Rona used:

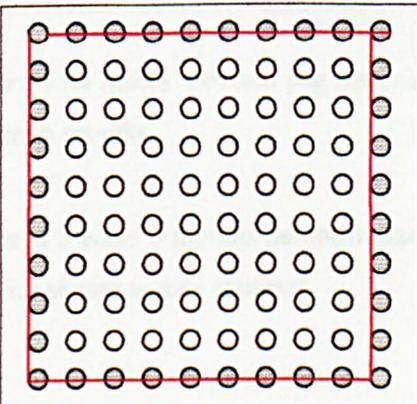
- linear organisation
 - 2+ lines repeated – multidirectional proximity placement and partial lines
- centre markings
 - marking the centre - sustained

Figure 6.52 Rona's devised peg pattern at

4 years

At 4 years, Rona used a basic element of pattern for the first time. In this work however, the linear organisation was less complex than at 3 years 7 months. This is likely to be because at 4 years Rona was coordinating colour organisation with spatial organisation for the first time.

4 years 3 months



In Figure 6.53, Rona used:

- linear organisation
 - 4 lines connected – unidirectional proximity placement and sustained lines

Figure 6.53 Rona's devised peg pattern at 4 years 3 months

At 4 years 3 months, Rona used connected lines for the first time, creating a square. Rona showed a keen interest in the spatial features of her pegboard work at this age, rather than the features of colour organisation. While placing the third line, she stated, "I'm making a big, big square."

4 years 7 months

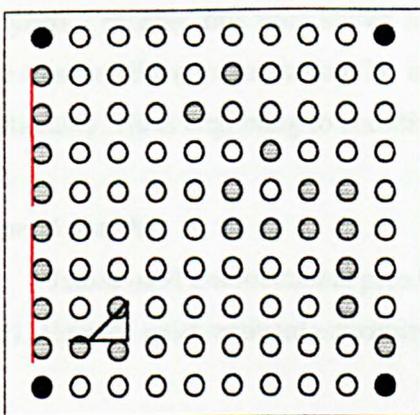
At Assessment 4, Rona returned to the use of the form of spatial organisation first used a year previously. However, she co-ordinated this with the highest level of colour organisation observed during the main study, Level 7 colour organisation. Over the year, Rona explored some aspects of spatial organisation but did not coordinate spatial elements as spatial patterns. It is likely that this was because her main preoccupation in terms of pattern-making was with the development of colour organisation. By the end of the year, Rona's skills in colour organisation were effectively coordinated with her secure skills in the spatial organisation of materials.

James

James is representative of the high group for spatial organisation.

3 years 6 months

At 3 years 6 months, James used unidirectional proximity placement to make a partial line in Mosaic Tiles 1 and multidirectional proximity placement to make a sustained line in Mosaic Tiles 2



In Figure 6.54, James used:

- linear organisation
 - proximity placement
 - multidirectional proximity placement and/or partial line
- corner markings
 - marking the corners - sustained

Figure 6.54 James' devised peg pattern at 3 years 6 months

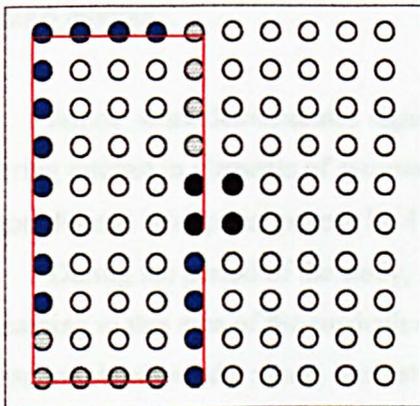
James at 3 years 6 months demonstrated basic linear organisation in a single context but this was not secure across contexts.

3years 11 months

At 3 years 11 months James used unidirectional proximity placement to make sustained lines in Mosaic Tiles1 and 2. He showed limited interest in the pegboard activity and worked only briefly.

4 years 2 months

James used multidirectional proximity placement to make sustained lines in Mosaic Tiles1 and 2. Regression, from unidirectional to multidirectional placement of tiles may have been the consequence of his new focus on colour organisation in this work



In Figure 6.55, James used:

- linear organisation
 - 2+ lines connected – multidirectional proximity placement and/or partial lines
- centre markings
 - marking the centre - sustained

Figure 6.55 James' devised peg pattern at 3years 11 months

At 4 years 2 months, this work shows James is moving on from basic linear organisation into more complex linear organisation. He is extending his repertoire of basic elements of symmetry. Additionally, He is beginning to coordinate colour and spatial organisation.

4 years 6 months

James used unidirectional proximity placement to make a sustained line in Mosaic Tiles1. He used unidirectional proximity placement to make a partial line in Mosaic Tiles2.

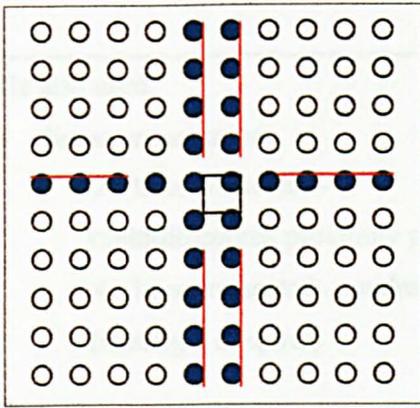


Figure 6.56 James' devised peg pattern at 4 years 6 months

In Figure 6.56, James made a spatial pattern.

He used:

- linear organisation
 - mid-point horizontal and vertical lines intersected - multidirectional/unidirectional proximity placement and sustained lines
- centre markings
 - marking the centre – sustained

James' work demonstrates significant but uneven progress over the year. There is a recurring interest in elements of symmetry during this period. The basic elements of symmetry are coordinated as a spatial pattern by 4 years 6 months.

During the period of the study, James demonstrated increasingly positive dispositions for learning in this area of the curriculum, and growing self-confidence. During the last assessment, he showed a strong interest in both the spatial organisation and the colour organisation elements of his work.

Dylan

Dylan is representative of the high group for spatial organisation.

3 years 6 months

Dylan used unidirectional proximity placement to make sustained lines in Mosaic Tiles1 and 2, as he continued to do throughout the following assessments.

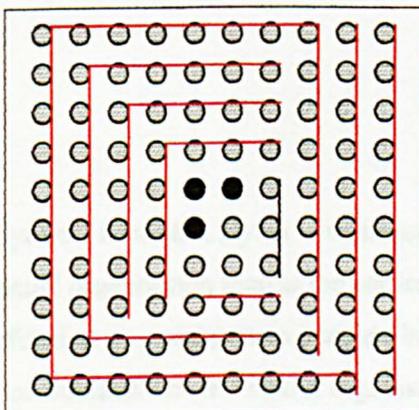


Figure 6.57 Dylan's devised peg pattern at 3 years 6 months

In Figure 6.57, Dylan used:

- linear organisation
 - multidirectional proximity placement - partial line
 - unidirectional proximity placement – sustained line
- centre markings
 - marking the centre – partial

He also used:

- linear organisation
 - 2+ lines connected – multidirectional proximity placement and/or partial lines
 - 4+ lines connected – unidirectional proximity placement and sustained lines (rectangle or spiral)

At 3 years 6 months, Dylan's work demonstrates secure basic linear organisation. He is also using relatively complex linear organisation and has made use of a basic element of symmetry.

3 years 11 months

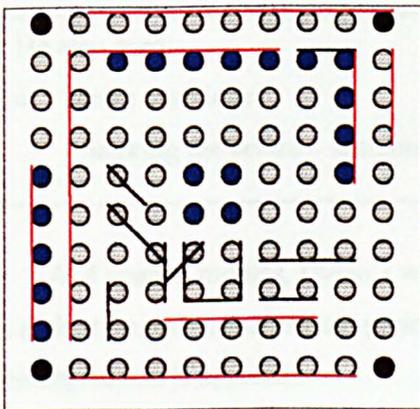


Figure 6.58 Dylan's devised peg pattern at 3 years 11 months

In Figure 6.58, Dylan made a spatial pattern. He used:

- centre markings
 - marking the centre – sustained
- corner markings
 - marking the corners - sustained
- linear organisation
 - proximity placement
 - multidirectional proximity placement partial line
 - unidirectional proximity placement – partial line
 - 2+ lines connected - unidirectional proximity placement – partial line

At 3 years 11 months, Dylan is working on a more complex coordination of different elements of spatial organisation than at the earlier assessment period. Dylan's work at 3 years 11 months is defined as a spatial pattern because he coordinates two of the basic elements of symmetry. He also coordinates Level 3 colour organisation with spatial organisation.

4 years 2 months

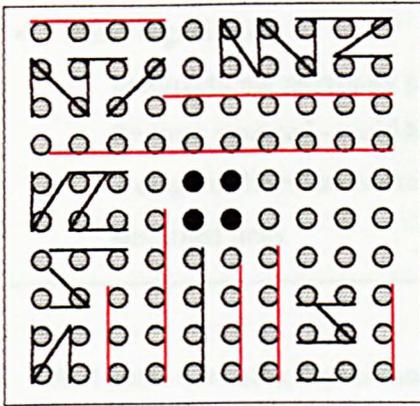


Figure 6.59 Dylan's devised peg pattern at 4 years 2 months

In Figure 6.59, Dylan used:

- linear organisation
 - proximity placement
 - multidirectional proximity placement partial line
 - unidirectional proximity placement - partial line
 - unidirectional proximity placement - sustained line
 - 2+ lines repeated - multidirectional proximity placement and/or partial lines

He also used:

- centre markings
 - marking the centre – sustained

At 4 years 2 months, Dylan's work is less complex in terms of spatial organisation than work at the two earlier assessment periods. He appeared interested in the activity and no reason for this regression is apparent.

4 years 6 months

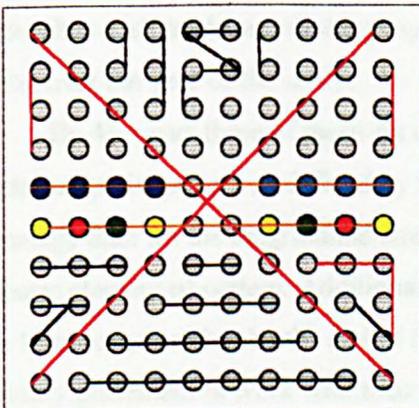


Figure 6.60 Dylan's devised peg pattern at 4 years 6 months

In Figure 6.60, Dylan made a spatial pattern.

He used:

- midpoint markings
 - marking a midpoint line
 - symmetrical placement – sustained line
- linear organisation
 - proximity placement
 - multidirectional proximity placement - partial line

He also used:

- linear organisation
 - unidirectional proximity placement – partial line
2+ lines repeated - multidirectional proximity placement and/or partial lines
 - 2 diagonal lines intersected – unidirectional proximity placement and sustained lines

At 4 years 6 months, Dylan made a symmetrical pattern, incorporating two basic elements of pattern, two midpoint lines, and two elements of complex linear organisation, two intersecting diagonal lines. This pattern used different elements to those used in Dylan's 2D pattern at 3 years 11 months. Dylan also co-ordinated spatial elements with Level 3 and Level 4 colour organisation.

The use of diagonal lines is a new development in Dylan's spatial work at this age. It seems possible that the corner markings, used at 3 years 11 months, where the endpoints of diagonals are marked, is a precursor for the intersecting diagonal lines.

Dylan worked in a self confident and committed way in work with tiles and pegs from the beginning of the study.

Discussion

Case study children set off from more varied starting points, at 3½ years, in terms of the spatial organisation strand of pattern-making than in terms of the colour organisation strand. There was a similarly wide variation in the complexity of spatial organisation achieved by the end of the year. However, the six children, whose work has been presented and analysed in the section above, all made significant progress within the spatial organisation strand of pattern-making over the year of the study.

By 4½ years three of these six children had made at least one successful attempt at devising a spatial pattern as defined by the criteria set out in Appendix 4. This is a higher percentage than for the longitudinal study as a whole. Five of the six children had used at least one basic element of pattern. Additionally, all case study children had shown competence in basic linear organisation by the end of the study, making sustained lines with unidirectional proximity placement in work with tiles and pegs. All children were at least repeating or connecting two or more lines.

As well as variation in the complexity of spatial organisation demonstrated, there also appears to have been considerable variation in the children's motivation to engage in spatial pattern-making. For example, although Rona showed well developed skills in organising materials spatially at 3½ years, she did not go on to develop skills in spatial pattern-making during the year. This is likely to be related to the fact that she made exceptionally good progress

in the colour organisation strand of pattern-making. At 3 and 4 years of age, despite sound basic skills, she was not as motivated to explore materials spatially as some other children in the study.

Nevertheless, in the process of examining the case study data presented above, as well as that of the other sixteen children, it became evident that there were as many commonalities as differences in the children's development. The starting points were not the same but there were particular milestones that most or many of the children passed by on a main pathway to basic linear organisation and then beyond this, towards the more complex spatial pattern-making exemplified in the work of James and Dylan.

Through the process of analysing complex case study material, hypothesised developmental pathways were gradually constructed. The early versions of these pathways were repeatedly checked back against the data until the developmental pathways best matched to the data had been constructed.

TOWARDS SPATIAL PATTERNS: AN HYPOTHESISED PATHWAY

The hypothesised pathways towards complex spatial organisation and the non-linear basic elements of pattern are presented below. There is an hypothesized initial pathway, from the random placement of play materials to the basic linear organisation of materials. Beyond this, there is an hypothesised pathway leading towards complex linear organisation. Additionally, there is an hypothesised pathway for non-linear spatial organisation, running parallel to the other pathways. This incorporates development towards several non-linear basic elements of pattern.

An Hypothesised Pathway To Basic Linear Organisation

Table 6.9 presents the hypothesised developmental pathway to basic linear organisation, leading through six hierarchically ordered levels of spatial organisation. This pathway is exemplified in Appendix 6.

Table 6.9 Hypothesised pathway to basic linear organisation

Level	Descriptors
1	• random placement
2	• proximity placement
3	• multidirectional proximity placement and/or partial line
4	• multidirectional proximity placement – sustained line
5	• unidirectional proximity placement - partial line
6	• unidirectional proximity placement - sustained line

An Hypothesised Pathway To Complex Linear Organisation

The second stage of the hypothesised developmental pathway to complex linear organisation is presented below. The pathway leads from basic linear organisation through a further nine hierarchically ordered levels of 2D spatial organisation.

As above, a logical analysis of linear organisation supports the hypothesised pathway. The behaviours focused on spatial organisation at each level of the pathway involve the sustaining, repetition, coordination and/or extension of behaviours focused on spatial organisation from the previous level.

Descriptors for each level relate to children's 2D work in the Pegs and Pegboard assessment activity.

Table 6.10 Hypothesised pathway to complex linear organisation

Level	Descriptors
7	<ul style="list-style-type: none"> • 2+ lines repeated - multi-directional proximity placement and/or partial lines • 2+ lines connected - multi-directional proximity placement and/or partial lines • 2 parallel lines – zigzag placement and partial lines (6+ pegs)
8	<ul style="list-style-type: none"> • 2+ lines repeated - uni-directional proximity placement and sustained lines • 2+ lines connected - uni-directional proximity placement and sustained lines • 2 parallel lines – zigzag placement and sustained lines
9	<ul style="list-style-type: none"> • 10 lines repeated - multi-directional proximity placement and/or partial line • 4+ lines connected - multi-directional proximity placement and/or partial line e.g. rectangle, spiral
10	<ul style="list-style-type: none"> • 10 lines repeated - uni-directional proximity placement and sustained lines (pegboard filled) • 4+ lines connected - uni-directional proximity placement and sustained lines e.g. rectangle, spiral
11	<ul style="list-style-type: none"> • Mid-point horizontal and vertical lines intersected - multidirectional/unidirectional proximity placement and sustained lines
12	<ul style="list-style-type: none"> • Diagonal line - multi-directional proximity placement and/or partial line
13	<ul style="list-style-type: none"> • Diagonal line - uni-directional proximity placement and sustained line
14	<ul style="list-style-type: none"> • 2 diagonal lines intersected - multi-directional proximity placement and sustained lines
15	<ul style="list-style-type: none"> • 2 diagonal lines intersected - uni-directional proximity placement and sustained lines

An Hypothesised Pathway To The Basic Elements of Pattern

Alongside and beyond the initial pathway to basic linear organisation, there are additional hypothesised pathways to the basic elements of pattern.

There are three categories within the basic elements of pattern. The three categories may appear in any order. With one exception, they appear concurrently with any level from Level 2 onwards of the hypothesised developmental pathways to basic and complex spatial organisation.

The three categories of nonlinear basic elements of pattern are:

- centre markings
- corner markings
- midpoint markings

There are short hypothesised pathways within each of the three categories and these are presented below. A logical analysis of the categories supports the hypothesised pathways. The behaviours at each level of the pathway involve the sustaining or elaboration of behaviours focused on spatial organisation from the previous level.

Table 6.11 Hypothesised pathway - centre markings

Level	Descriptors
1	• marking the centre - partial
2	• marking the centre - sustained
3	• enclosing the centre - partial
4	• enclosing the centre - sustained

Table 6.12 Hypothesised pathway – corner markings

Level	Descriptors
1	• marking the corners- partial
2	• marking the corners- sustained

Table 6.13 Hypothesised pathway –midpoint markings

Level	Descriptors
1	• marking two midpoints
2	• marking a midpoint line – unidirectional proximity placement – sustained line • marking a midpoint line –symmetrical placement – sustained line

Marking a midpoint line can only appear once level 6 basic linear organisation is established.

Summary

A logical analysis of spatial pattern-making as a task supports the hypothesised pathways, from a pathway to basic linear organisation, through a pathway to complex linear organisation, and with pathways to the basic elements of pattern alongside this. Behaviours focused on spatial organisation at each level of the pathways involve the co-ordination, sustaining, repetition or elaboration of behaviours focused on spatial organisation from a previous level.

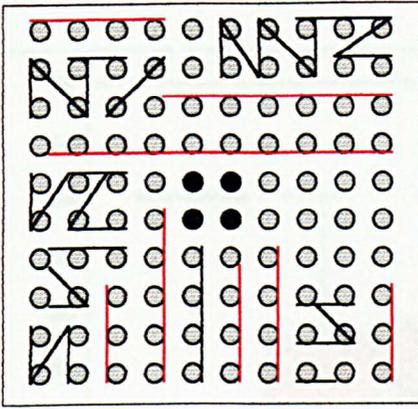
The hypothesised developmental pathways for spatial organisation were developed through an analysis of the complex qualitative data and they were supported by a logical analysis of task demands. Following this, quantitative data analysis was used to examine the hypothesised pathways.

TOWARDS SPATIAL PATTERNS: QUANTITATIVE DATA

The hypothesised developmental pathway towards complex spatial organisation and spatial pattern-making, like the hypothesised pathway towards complex repeating patterns, is based on the assumption that children make progress over time. Again the expectation is that, if the pathway is valid, progress can be evidenced through children's work at increasingly advanced levels over time. A statistical analysis of main study data was undertaken to examine the nature and extent of children's progress towards complex spatial organisation and spatial pattern-making in the main study. Again results do need to be treated with some caution for a number of reasons. Firstly, children's progress can only be assessed using a scoring system, which is based on the levels of the hypothesised pathways. Additionally, the sample for the longitudinal study is small and the data collected represents only a snapshot of particular points in development.

The quantitative analysis of the spatial organisation data does not use children's achieved levels directly, unlike the quantitative analysis of colour organisation data. Instead a scoring system has been developed to take account of the complexity of the hypothesised development in the spatial organisation strand of pattern-making. Children were given initial scores relating to their achieved level in the hypothesised pathways for linear organisation. Scores relating to children's use of nonlinear basic elements were then added to this initial score.

The scoring system is exemplified below, using the devised pattern in Figure 6.59.



Scoring system for Figure 6.59

- 2+ lines repeated - multidirectional proximity placement and/or partial lines
Level 7 Pathway to complex linear organisation
Score : 7
 - marking the centre – sustained
Level 2 centre markings
Score : 2
- Total score: 9

An exploratory data analysis technique was used in order to explore the distribution of the scores for spatial organisation achieved by children over time, with scores grouped as stages. A scatter diagram and a measure of rank correlation were used to explore the relationship between children's age and their stage in terms of spatial organisation. Finally, statistical tests on main study data were performed to assess whether significant progress could be evidenced in the work of children at 4½ years, as compared to children at 3½ years, as well as at time intervals between these ages. Quantitative data are presented from the Pegs and Pegboard assessment activity.

Exploratory Data Analysis – Boxplots

A boxplot was used to explore some of the spatial organisation data from the 24 children in the longitudinal study. The 24 children from the longitudinal study were identified as working at a stage from 1 to 6, based on spatial organisation scores in work with pegs. The assessment periods were for children at 3½ and 4½ years, as well as at two intermediate points. Over the four assessment periods, children's ages ranged from 42 to 56 months.

A boxplot for each stage of the hypothesised sequence provides a graphical representation of the dispersion of ages for children working within this stage. Each boxplot shows the median age for children working within a stage, the middle 50% of observations, as well as the highest and lowest ages. Outliers, the extreme cases beyond this, are also indicated.

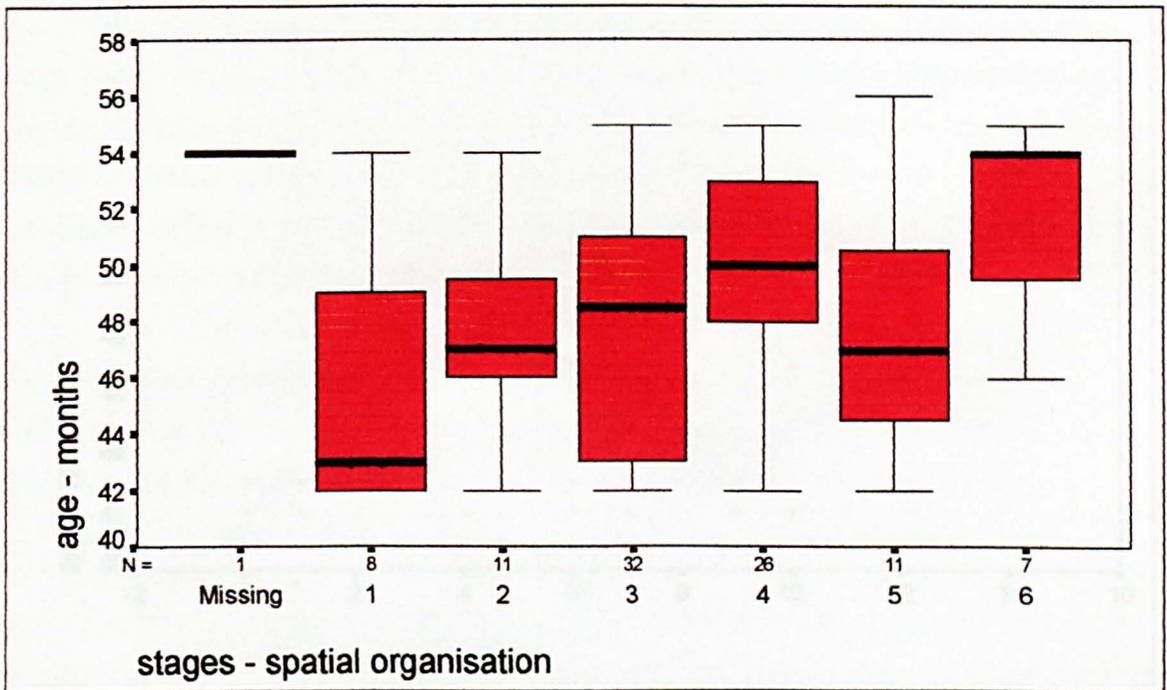


Figure 6.61 Boxplot for spatial organisation stage by age

Discussion

The boxplot exploration of spatial organisation data provides some support for the hypothesised developmental pathways towards spatial pattern-making. The chart provides evidence of a gradual increase in the median age of children working at each stage in the sequence, with the exception of children working within Stage 5. An explanation for the problematic profile of Stage 5 children in the sequence may lie in the relatively small sample size and the particularly small numbers of high and low scoring children.

Exploratory Data Analysis: A Scatter Diagram and Measure of Correlation

Additionally, a scatter diagram and a measure of rank correlation were used to explore the relationship between children's age and their scores in terms of spatial organisation. The 24 children from the longitudinal study were identified as working at a stage from 1 to 6, based on their spatial organisation scores in work with pegs. The assessment periods were at 3½ and 4½ years, as well as at two intermediate points. Over the four assessment periods, children's ages ranged from 42 to 56 months.

To provide further information about the strength of this relationship, a rank correlation measure of correlation was used. This was Spearman's rho. This particular measure was used because the samples comprised ordinal scores.

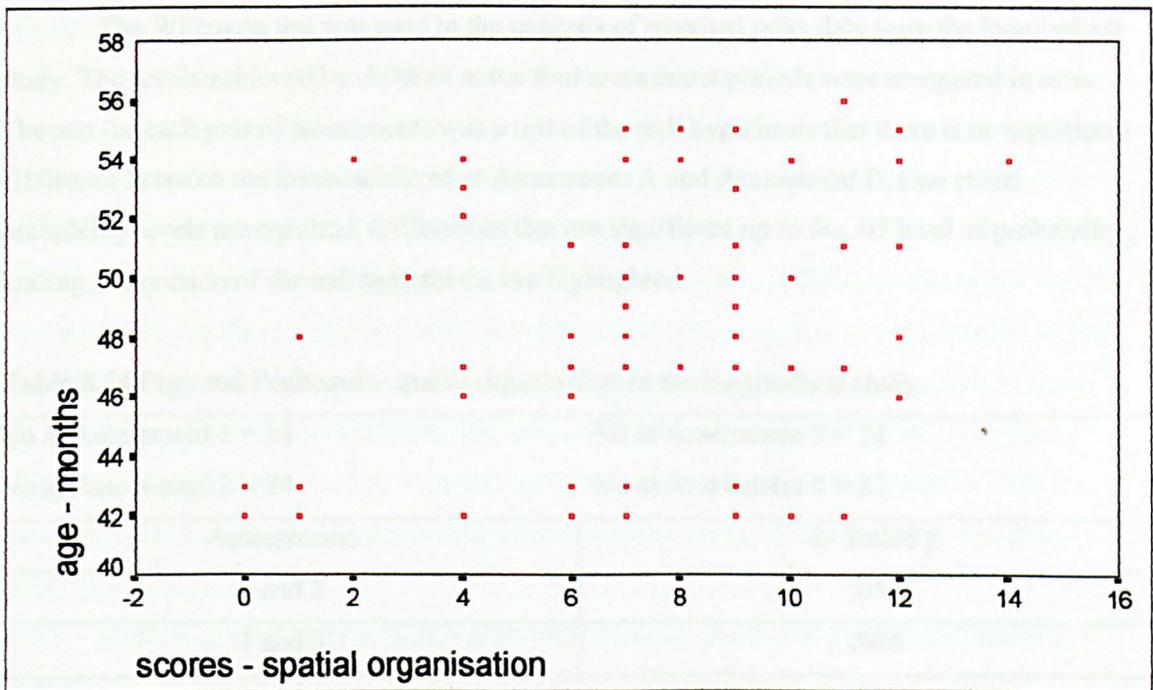


Figure 6.62 Scatter Diagram – spatial organisation scores by age

The Scatter Diagram shows a weak positive relationship between the two variables, age and spatial organisation score.

From the results of the correlation carried out on the age of the children and their spatial organisation score, a significant positive association was found ($\rho = 0.2511$, $N = 24$, $p = 0.007$). It was concluded that, as children's age increases between $3\frac{1}{2}$ and $4\frac{1}{2}$ years, there is an increase in their spatial organisation scores.

Discussion

Quantitative analysis demonstrates a modest but significant correlation between age and children's spatial organisation scores. This analysis provides additional evidence, supporting the hypothesised developmental pathways, towards complex spatial pattern-making.

Statistical Data

A statistical analysis of spatial organisation data was carried out in order to examine further the nature and extent of the progress made by children through the levels of the hypothesised developmental pathways over time.

Statistical tests were performed to test the null hypothesis that there is no significant difference between the levels achieved by children at the different assessment periods. Non parametric tests were selected because the samples comprise ordinal scores and therefore do not meet the conditions for use of parametric tests.

Wilcoxon Test

The Wilcoxon test was used in the analysis of matched pairs data from the longitudinal study. The levels achieved by children at the four assessment periods were compared in turn. The test for each pair of assessments was a test of the null hypothesis that there is no significant difference between the levels achieved at Assessment A and Assessment B. One tailed probability levels are reported. Differences that are significant up to the .05 level of probability, leading to rejection of the null hypothesis, are highlighted.

Table 6.14 Pegs and Pegboard – spatial organisation in the longitudinal study

No at Assessment 1 = 24		No at Assessment 3 = 24	
No at Assessment 2 = 24		No at Assessment 4 = 23	
Assessments		1- Tailed p	
1 and 2		.051	
1 and 3		.004	
1 and 4		.005	
2 and 3		.239	
2 and 4		.041	
3 and 4		.167	

Mann-Whitney U Test

The Mann-Whitney U test was used in the analysis of data from the larger unrelated samples. The levels achieved by children at the assessment periods, for children at 3½ and 4½ years were compared. The test was a test of the null hypothesis that there is no significant difference between the levels achieved at Assessment 1 and Assessment 2. One tailed probability levels are reported. Differences that are significant up to the .05 level of probability, leading to rejection of the null hypothesis, are highlighted.

Table 6.15 Pegs and Pegboard – spatial organisation in the cross-sectional study

No at Assessment 1 = 49		No at Assessment 4 = 48	
Assessments	U	1- Tailed p	
1 (No = 50) and 4 (No = 48)	574.0	.000	

Discussion

In the longitudinal study, a comparison of spatial organisation scores for children at 3½ and 4½ years results in rejection of the null hypothesis. Similarly, a comparison of spatial

organisation scores for children in the larger unrelated samples results in rejection of the null hypothesis.

Using scores, which are based on levels from the hypothesised developmental pathways for spatial organisation, the results demonstrate a significant difference between children's achievement at 3½ and 4½ years. These results provide further support for the hypothesised developmental pathways towards spatial pattern-making.

However, the tests of progress taking account of the two additional assessment periods for the children in the longitudinal study are of particular importance in a consideration of the hypothesised pathways. Progress for children in the longitudinal study between two or three assessment periods is likely to be less than progress between 3½ and 4½ years. Evidence of significant progress within a 3 or 4 month period or within a 5 to 7 month period is likely to indicate children moving up through one or two levels of the hypothesised pathways, rather than through several levels.

There is in fact some evidence of children making significant progress in terms of spatial organisation scores within the medium time assessment periods but not within the shortest periods. In a comparison of children's scores at Assessment 1 and 2, Assessments 2 and 3, as well as Assessments 3 and 4, the null hypothesis cannot be rejected for any of the three assessment periods. The statistical analysis does not find significant differences between the performance of children at these assessment periods. However, in a comparison of children's scores at Assessment 1 and 3, as well as at Assessments 2 and 4, results are significant. The null hypothesis can be rejected in these cases. In the medium time intervals, children do make significant progress in terms of spatial organisation scores.

In conclusion, the analysis of quantitative data provides some but qualified support for the hypothesised developmental pathways within the spatial organisation strand of pattern-making. The case studies above, however, highlight the need to be alert to individual differences in development when proposing any generalised pathway of development. There is no evidence relating to within-level developments but children's development was not uniformly progressive.

During the study, only a minority of children moved steadily through the levels, with an increase in performance at each assessment period. There was considerable variation in children's interest in spatial pattern-making and particularly in the extent to which children explored the spatial forms identified as the basic elements of symmetry. As in the case of Rona, low interest in spatial pattern-making may sometimes have been related to a child's stronger interest in the colour organisation strand of pattern-making.

As children developed their particular interests and related skills in the two distinct strands of pattern-making, they also began to develop knowledge and concepts relating to pattern and pattern-making. The ways in which this understanding developed over the year of the study are considered in the final section of the chapter.

**PATTERN PERCEPTION AND UNDERSTANDING OF THE WORD 'PATTERN':
DEVELOPMENT BETWEEN THE AGES OF 3½ AND 4½ YEARS**

Children's pattern perception at 3½ and 4½ years, as well as their declarative knowledge or understanding of the word 'pattern' was examined in Chapter 5. The evidence reviewed indicated some but relatively small differences in children's competencies at these ages. The second research question asks:

2. Where do knowledge understanding and skills in pattern-making begin and how do they develop between the ages of 3½ and 4½ years?

To examine the ways in which pattern perception and children's declarative knowledge or understanding of the word 'pattern' developed over the period of the study, six of the case studies considered above are re-examined with a new focus on this aspect of young children's development. The commonalities as well as the differences in children's development are reviewed.

**PATTERN PERCEPTION AND UNDERSTANDING OF THE WORD 'PATTERN':
QUALITATIVE DATA**

Aaron

Aaron was in low groups for both colour and spatial organisation. At 3 years 6 months, Aaron participated in assessment activities without talking and made no response to the question about which bead necklace he liked best. He showed more interest in and enjoyment of assessment activities at 3 years 11 months. For example, he counted tiles and talked about the colours during this work.

At 4 years 2 months Aaron focused attention on the size of his string of beads, "I'm making a big one... Look big!" In work with pegs he placed pegs as if racing to fill the pegboard before his friends filled theirs. However, in Mosaic Tiles 2, Aaron showed some understanding of pattern as a sequence of colours in that, following a request to make a pattern, he verbally planned a colour sequence before starting to place tiles, "I'm doing black, red, black." He went on to create a sustained similarity group of black tiles.

By 4 years 6 months, Aaron showed a greater responsiveness to adult talk. When asked which necklace he liked best, he responded, pointing to Pudsey Bear. He appeared to interpret the question as one about his favourite bear, since Pudsey Bear was the one out of the four bears not wearing a necklace. When asked to make a necklace with a pattern for Baby Bear, Aaron responded by asking, "A big un? Why don't she want a red un?" He appeared to be making

sense of the word 'pattern' as something other than a colour, interpreting it as a word relating to size.

Over the year of the study, there is some evidence of Aaron struggling to make sense of the meaning of the word pattern. He makes increasing use of contextual clues and does begin to focus on the meaning of pattern in terms of a colour sequence, while working with tiles. By the end of the study, however, Aaron shows continuing confusion about the relationship between pattern and size.

Lauren

Lauren was in low groups for both colour and spatial organisation. At 3 years 6 months, Lauren pointed to the symmetrical pattern when asked which of three necklaces she liked best. Asked what she liked about it she responded, "That one, that one, that one. 3,6,13,2." Lauren was very talkative during the subsequent bead threading activities but with most talk related to the imaginative context of the assessment activity. In other contexts she talked about successfully managing the task, "I can do it" and she made a few isolated references to colour.

At 4 years, Lauren chatted solely about events extraneous to the activity she was engaged in. However, following this, at 4 years 4 months, Lauren requested a colour name in work with beads. Additionally, she attempted to name some colours in work with tiles and expressed her love of the blue tiles, "I love them uns."

At 4 years 6 months, Lauren pointed to the repeated pattern when asked which necklace she liked best. Asked what she liked about it, at this age Lauren responded, "colour and black." In response to the invitation to make a necklace with a pattern for Baby bear, she responded, "These?" pointing to beads in the tray. She seemed to interpret pattern as meaning the colour beads that Baby bear would like and said, "Baby bear don't like this necklace," pointing to the green and yellow beads used in modeled pattern-making.

At 4 years 6 months, in response to the invitation to make a pattern with tiles, Lauren talked enthusiastically about her work as if it were a pattern, linking the idea of a sequence of colours to the word, 'pattern.' As she placed tiles she said, "Red, black, red.... Do you like that pattern? Can't do it one time. Do you like my pattern?"

Over the year of the study, there is some evidence of Lauren beginning to make sense of the meaning of the word pattern as a sequence of colours, perhaps for her a sequence of favourite colours. She does not seem to have a concept of pattern incorporating the spatial dimension of pattern-making.

Andrew

Andrew was in medium groups for both colour and spatial organisation. At 3 years 7 months, Andrew pointed to the repeated pattern when asked which of three necklaces he liked best. Asked what he liked about it, he pointed to the necklace again. In response to the invitation

to make a necklace with a pattern for Baby bear, Andrew responded by stating, "Okay. I might do big uns." It was not clear whether the reference was to big beads or a long necklace. At this age, Andrew focused on size again and also the representational quality of his work when invited to make a pattern with tiles, "I'm making a big snake." He worked mainly silently during other assessment activities at this age.

Andrew's preoccupation with size and the related representational qualities of his work continued and was developed at 3 years 11 months. In Bead Threading, he counted beads and talked about size, "I'm getting bigger....Long snake, look at mine." In work with pegs, focusing on the shape of his spatial arrangement, Andrew commented, "Look, like it's a house." In contrast, In Mosaic Tiles 2, he focused on the colour of tiles, naming the colours of the tiles of his repeating pattern as each tile was placed.

At 4 years 3 months, Andrew worked with little talk, except to comment on the blue pegs he was using to fill the pegboard, "I'm doing them all blue." At 4 years 7 months, Andrew pointed to the symmetrical pattern when asked which of three necklaces he liked best. Asked what he liked about it, he pointed to a yellow bead, saying, "That one." In response to the invitation to make a necklace with a pattern for Baby bear, Andrew responded by asking, "Can I put different colours on?" He similarly referred to 'different colours' in response to the first invitation to make a pattern with mosaic tiles. . and made a third reference to 'different colours' in bead threading, "Mine's a snake, aint it? Think it is. You can do different colours Ashley. You have to get it right up to here." He indicated the end of the string.

Over the year of the study, progress is evident in Andrew's developing understanding of the word pattern. By 4½ years he seems to make sense of pattern as a sequence of contrasting colours. In talking about his work, at 4½ years, Andrew sustains his early preoccupation with length and with the representational quality of the forms created. He does not seem to have a concept of pattern incorporating the spatial dimension of pattern-making, although his pegboard work at 4 years 3 months was categorised as a spatial pattern.

Gemma

Gemma was in medium groups for both colour and spatial organisation. At 3 years 6 months, Gemma pointed to Pudsey bear, the bear without a necklace, when asked which of three necklaces she liked best. In response to the invitation to make a pattern with red, yellow and green beads, Gemma said "red" as she picked up the first red bead and then, "patterns, patterns," as she threaded the fifth bead of the necklace. There was no evidence of patterning in her sequence. Apart from naming the colour of another bead, Gemma worked at other assessment activities without talking.

At 3 years 11 months, Gemma made frequent and accurate reference to colour names while engaged in all assessment activities but she made no further reference to pattern. At 4

years 2 months, she worked mainly silently except to say, "red, black,red," as she made a repeated pattern with red and black tiles.

At 4 year 6 months, Gemma pointed to Baby bear's necklace, the necklace with no patterned arrangement of beads, when asked which of three necklaces she liked best. She did not respond to the question about her choice. Again, Gemma talked little during other activities, although she made repeated patterns in several assessment activities. In pegboard work, Gemma seemed to focus on the representational qualities of her work, rather than pattern features. She said, "a face," before starting to place tiles. However, in response to the spatial forms created early on in the work, she then commented, "That's the house and that's the lady."

Over the year, Gemma developed fluent procedural skills, devising 2 unit repeating patterns and organising materials spatially in relatively complex ways. However, she made only one early reference to pattern and case study data provides no clues as to any developing understanding of pattern.

Rona

Rona was in a high group for colour organisation and a medium group for spatial organisation. At 3 years 7 months, Rona said, "Baby bear's," and pointed when asked which necklace she liked best. This was the necklace with a random arrangement of beads. Questioned about her choice, she pointed to a bead, saying, "That one." Asked to make a necklace with a pattern on it for Baby bear, Rona responded initially by selecting four beads and arranging these on the table, as illustrated in Figure 6.61. She said, "I'm making a square with these."

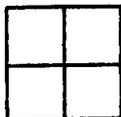


Figure 6.63 Rona's response to Teddy's Beads 3

Rona then went on to thread the beads. During other bead threading activities and during work with pegs, Rona confidently chatted about herself, as well as naming the colours of play materials and other objects.

At 4 years, Rona similarly talked about herself and colours, as well as counting a row of pegs. In Mosaic Tiles 1, she stated the colours, red and black, of a repeated pattern before going on to make it. Following this, at 4 years 3 months, Rona named the colours of the two repeating patterns made with tiles. Making a square with pegs, she described this, "I'm making a big, big square." In Bead Threading seemingly reminded of the tail of a kite, she commented, towards the end of threading, "It looks like I'm doing a kite."

At 4 years 7 months, Rona pointed to the symmetrical pattern, when asked which of three necklaces she liked best. She explained her choice, "It's nice 'cos its got yellow and green

on. Mine is yellow but Emily's favourite is green." Responding to the invitation to devise a necklace with a pattern for Baby bear, Rona stated, "I want red and orange," before going on to devise this pattern. At this age, in Bead Threading, Rona devised two sequences of repeated patterns and talked confidently about patterns and about favourite colours again, "It's a lovely pattern this. I'm going to do yellow and purple, that would be a nice pattern, wouldn't it?" While making a complex sequence of repeating patterns with pegs, Rona chatted continuously about herself, her sister and home events. She made no further reference to pattern but described her pegboard work after three lines of repeating patterns, "I've been making a firework."

Over the year of the study, Rona seemed to develop a concept of pattern, which incorporates her strong aesthetic awareness and enjoyment of particular colour combinations. Her excitement at the variety of pleasurable combinations seems to be expressed through the metaphor of the firework during pegboard work. At this age, Rona did not seem to have a concept of pattern incorporating the spatial dimension of pattern-making. Instead, she uses her well developed vocabulary of shape to describe spatial work and relates spatial forms to experiences, for example observing the tail of a kite.

Dylan

Dylan was in high groups for both colour and spatial organisation. At 3 years 6 months, Dylan pointed to the symmetrical pattern when asked which of three necklaces he liked best. Asked what he liked about it, he pointed to the single yellow bead in the centre of the pattern. It is possible that Dylan recognised the yellow bead as the central point of the symmetrical pattern but there is no confirming evidence at this age. In work with pegs at 3 years 6 months, Dylan made reference to a representational feature of his work. He referred to a pair of pegs of the same colour and placed next to each other as eyes, "Look, they're eyes."

At 3 years 11 months, Dylan made a spatial pattern using two elements of symmetry. Towards the end of working, Dylan said, "I done a pattern." He used the word 'pattern' less appropriately in Bead Threading. While threading a seemingly random arrangement of beads, Dylan said, "Two patterns." The intended meaning was not clear. At 4 years 2 months, Dylan made no further reference to pattern features and he did not use the word 'pattern.'

At 4 years 7 months, Dylan pointed to the random arrangement of beads when asked which of three necklaces he liked best. Questioned about what he liked about it, Dylan said, "Can make one of those." Although demonstrating confident skills in devising repeated and symmetrical patterns, he appeared to be less responsive to the patterning of model sequences than a year earlier. However at 4 years 7 months, Dylan made one reference to 'pattern', suggesting a developing understanding of pattern in the context of his own work. Before starting work on a pattern that incorporated complex spatial and complex colour organisation, Dylan said, "I can do them patterns."

Over the year of the study, Dylan appeared to develop an understanding of pattern as a term to apply to symmetrical arrangements of pegs. His work with a variety of play materials at 4 years 7 months, including work with construction sets, showed a particularly mature awareness of symmetry. Although, by 4 years 7 months, Dylan was confidently devising repeating patterns in response to invitations to make patterns, he did not learn to make explicit use of the word 'pattern' in colour organisation contexts over the year of the study.

Discussion

Children's knowledge and understanding about pattern at 3½ and 4½ years was examined in the previous chapter. The evidence reviewed indicated some but relatively small differences in the knowledge and understanding about pattern of children at the two ages. However, a more detailed examination of development in the context of individual case studies does provide evidence of some significant development for a minority of children over the year of the study.

At the earliest stages of development, case study children showed no evidence of attention to the adult's use of the word 'pattern.' Additionally, several children showed an early and continuing attention to the representational features of their work. They talked about representational features rather than pattern features even when devising spatial or repeating patterns.

Several children, including Aaron and Andrew in the case studies reported above, evidenced early development as they attempted to make sense of the word 'pattern.' Often children first interpreted 'pattern' as an unfamiliar word relating to colour or sometimes to size. During the year of the study, some children explored an understanding of 'pattern' as a sequence of different and aesthetically pleasing colours. Some, for example Rona, began to talk about different coloured patterns in the context of repeating pattern work.

Over the year of the study, several children developed a personal and unconventional understanding of pattern in the context of colour organisation but without a complementary understanding in the context of spatial organisation. Dylan was unusual in his development in that he seemed to have a stronger awareness of the spatial than the colour dimension of pattern.

In summary, the development of children's concepts of pattern seemed to be particularly individualistic. Development, where evident, appeared to be related to children's individual interests and preoccupations. Many children appeared to make no progress or relatively limited progress in this area over the year of the study. It is therefore not possible to outline any common pathways of development in relation to either pattern perception or children's abilities to articulate concepts of pattern for the age group studied.

Conclusion

In order to examine the second, third and fourth research questions, this chapter has considered a wide range of evidence relating to the development of children's pattern-related knowledge, understanding and skills between the ages of 3½ and 4½ years. It has focused on the commonalities and the differences in children's development towards and within pattern-making, focusing in turn on the colour organisation and spatial organisation strands of pattern-making. It has also considered development in terms of pattern perception and children's abilities to articulate concepts of pattern.

This chapter has considered a range of evidence relating to developmental pathways from early patterning play towards complex colour and spatial organisation. The evidence has supported many of the key features of the hypothesised pathways, although some hypothesised features appear problematic. Despite the supportive evidence for common pathways of development, throughout the chapter there has been a complementary emphasis on the significance for development of children's individual interests and their motivation to engage in aspects of early patterning play and pattern-making. There do seem to be individual differences in the detailed pathways taken towards knowledge, understanding and skills in pattern-making, and these seem to be related in part to children's individual interests and to differences in motivation.

There are clear differences in children's starting points, in terms of the three pattern-related aspects of development considered. There are also clear differences in children's rates of development at this age. For example, in terms of the colour organisation strand of pattern-making, some children evidence no progression through the hypothesised levels of the developmental pathway. Other children in contrast progress through four levels over the year. Again, rates of development seem to be partly related to children's interests and to their motivation to engage in particular kinds of play.

In Chapter 7, these individual differences in development are considered from a new perspective. They are examined in terms of possible gender differences in early development. Additionally, they are reviewed in the context of individual differences across other key dimensions of development, dimensions of development identified as potentially related to the development of pattern-related competencies.

CHAPTER 7

DEVELOPMENT IN PATTERN: A RELATIONSHIP WITH OTHER DIMENSIONS OF DEVELOPMENT?

In Chapter 7 the data relating to the fifth main study research question, restated below, is presented and analysed:

5. Do individual differences in the development of knowledge, understanding and skills in pattern-making relate systematically to differences across other dimensions of development?

In the main study, the dimensions of development reviewed in relation to children's knowledge, understanding and skills in pattern-making at 3½ and 4½ years were language, number, spatial abilities, music and drawing. The potentially significant strand of music considered was the strand of abilities in replicating rhythmic patterns. Additionally, children's understanding of colour words was considered as a potentially significant strand of developing language skills.

In examining the fifth research question, the first aspect of pattern-making to be considered in the context of these wider dimensions of development is colour organisation. Spatial organisation is the second. Additionally, the relationship between gender and both strands of children's knowledge, understanding and skills in pattern-making is examined. The examination takes into account both the colour organisation and the spatial organisation strands of pattern-making.

COLOUR ORGANISATION

Measures of colour organisation were used to examine the possibility of systematic relationships between children's knowledge, understanding and skills in the colour organisation strand of pattern-making at 3½ and 4½ years and competencies in other areas of development. Measures were derived from the hypothesised developmental pathway towards complex colour organisation, outlined in Chapter 6.

The Association Between Colour Organisation and Key Aspects of Cognitive Development

Statistical tests were used to obtain measures of the association between children's knowledge, understanding and skills in colour organisation at both 3½ and 4½ years and their scores across the key areas of development specified above. The test used to obtain measures of rank correlation between variables was Spearman's rho. Statistical tests were used to test the null hypothesis that there is no relationship between children's knowledge, understanding and skills in the colour organisation strand of pattern-making at 3½ and 4½ years and their scores across other key areas of development.

In the two tables below, one tailed probabilities are reported. Measures of association significant at least at the .05 level of probability, leading to rejection of the null hypothesis, are highlighted.

Table 7.1 The association between colour organisation and key aspects of cognitive development at 3½ years

Aspect of cognitive development	Spearman's rho	1 Tailed p
Language (N = 50)	.4070	.002
Number (N = 50)	.3602	.005
Spatial Abilities (N = 50)	.2192	.063
Replicating Rhythmic Sequences (N = 49)	.1509	.150
Drawing (N = 49)	.2927	.021
Colour Matching and Naming (N = 49)	.3405	.008

Table 7.2 The association between colour organisation and key aspects of cognitive development at 4½ years

Aspect of cognitive development	Spearman's rho	1 Tailed p
Language (N = 48)	.4493	.001
Number (N = 47)	.4842	.000
Spatial Abilities (N = 49)	.3640	.005
Replicating Rhythmic Sequences (N = 48)	.3093	.016
Drawing (N = 48)	.4432	.001
Colour Matching and Naming (N = 47)	.4746	.000

Discussion

The statistics demonstrate a convincing association between children's knowledge, understanding and skills in the colour organisation strand of pattern-making at 3½ years and their competencies in terms of language, number, drawing, as well as colour matching and naming. There are less clear associations with spatial and rhythmic abilities.

At 4½ years, the statistics demonstrate a convincing association between children's knowledge, understanding and skills in the colour organisation strand of pattern-making and their competencies across all areas of cognitive development reviewed.

The predominance of highly significant levels of association suggests that there may be a single factor having a generalised effect on scores. It seems possible that general intelligence is

a factor impacting on children's competencies across all identified areas of cognition. Meadows (1993) discusses the work of Spearman, Burt and Eysenck, who believed that a general intelligence, hypothesised as fixed and innate, informed educational achievement. Present study findings suggest that general intelligence may inform scores across diverse areas of achievement, including the colour organisation strand of pattern-making. However, there is no evidence to conclude that this intelligence is either fixed or innate.

If general intelligence is informing achievement in this aspect of pattern-making, it is necessary to provide an explanation for the less convincing levels of association between colour organisation and children's scores in the spatial and rhythm assessments at 3½ years. The measure of association between spatial abilities and colour organisation, at a probability level of .063, lies just outside the conventionally accepted level of .05. However, it remains a less convincing association than other associations at 3½ years. The less convincing nature of this association may relate to the very high proportion of 3½ year olds, 48% of the sample, demonstrating competencies only at the earliest two stages of drawing development.

This explanation may be stronger still in relation to children's rhythmic abilities at 3½ years. At this age, 74% of children failed to score on the test. At 4½ years, the scores for drawing and rhythmic abilities were more widely dispersed, so the assessments for this age group discriminated more effectively between children. At 4½ years just 6.1% of children demonstrated drawing competencies at stages 1 and 2, in contrast to the 48% of children at 3½ years. Scores for the lower 51% of children at 4½ years showed a spread between stages 1 and 5. On the test of rhythmic abilities the percentage of children not scoring dropped from 75% at 3½ to 24.5. % at 4½ years. In the context of children's emergent mark-making and rhythmic abilities at 3½ years, the relative weakness of the rhythm and drawing assessments in discriminating between children may account for the failure to find the convincing associations with colour organisation that were found at 4½ years.

In conclusion, it seems likely that there is a single factor such as general intelligence impacting on the development of children's knowledge, understanding and skills in the colour organisation strand of pattern-making between 3½ and 4½ years.

SPATIAL ORGANISATION

Paralleling the analysis of colour organisation, measures of spatial organisation at 3½ and 4½ years were used to examine the possibility of systematic relationships between children's knowledge, understanding and skills in the spatial organisation strand of pattern-making and competencies in other key areas of cognitive development. Measures at 3½ and 4½ years were derived from the hypothesised developmental pathways towards spatial organisation outlined in Chapter 6.

The Association Between Spatial Organisation and Key Aspects of Cognitive Development

Statistical tests were used to obtain measures of the association between children's knowledge, understanding and skills in spatial organisation at both 3½ and 4½ years and their scores across the key areas of development identified. The test used to obtain measures of rank correlation between variables was Spearman's rho. Statistical tests were used to test the null hypothesis that there is no relationship between children's knowledge, understanding and skills in the spatial organisation strand of pattern-making at 3½ and 4½ years and scores across other key areas of development.

In the two tables below, one tailed probabilities are reported. Differences significant at at least the .05 level of probability, leading to rejection of the null hypothesis, are highlighted.

Table 7.3 The association between spatial organisation and key aspects of cognitive development at 3½ years

Aspect of cognitive development	Spearman's rho	1 Tailed p
Language (N = 50)	.1318	.181
Number (N = 50)	.1066	.231
Spatial Abilities (N = 50)	.6647	.000
Replicating Rhythmic Sequences (N = 49)	.2284	.057
Drawing (N = 49)	.3520	.007
Colour Matching and Naming (N = 49)	.1285	.189

Table 7.4 The association between spatial organisation and key aspects of cognitive development at 4½ years

Aspect of cognitive development	Spearman's rho	1 Tailed p
Language (N = 48)	.1173	.214
Number (N = 47)	.3307	.012
Spatial Abilities (N = 48)	.3807	.004
Replicating Rhythmic Sequences (N = 47)	.3864	.004
Drawing (N = 48)	.1754	.117
Colour Matching and Naming (N = 47)	.1498	.157

Discussion

The nature of the associations between children's scores across key areas of cognitive development and spatial organisation scores contrasts markedly with the previously reported

associations with colour organisation. The associations with spatial organisation seem less consistent and more discrete.

The statistics demonstrate a convincing association between children's knowledge, understanding and skills in the spatial organisation strand of pattern-making at 3½ years and their competencies in drawing and spatial abilities. There is a less clear association with rhythmic abilities, with the probability level of .057 lying just outside the conventionally accepted .05 probability level.

At 4½ years, the statistics again demonstrate a convincing association between children's knowledge, understanding and skills in the spatial organisation strand of pattern-making and their spatial abilities. This is a strong and consistent association, suggesting that the two assessments may tap similar aspects of developing cognition.

The statistics demonstrate a stronger association at 4½ years than at 3½ years between children's knowledge, understanding and skills in the spatial organisation strand of pattern-making and rhythmic abilities. This association at 4½ years is as convincing as the association with spatial abilities. The argument presented above, concerning the problematic nature of the assessment of rhythmic abilities at 3½ years, may explain the less convincing findings of an association with rhythmic abilities at the younger age. The strength of the association with rhythmic abilities at 4½ years suggests a relationship between children's abilities to pattern physical elements in space and over time in work with pegs and their abilities to pattern physical elements over time in work with sound. Analysis of the case study material in this area, which is beyond the bounds of this thesis, would be useful in further elucidating the nature of this specific relationship.

In contrast to the findings for children at 3½ years, the statistics also demonstrate a clear association at 4½ years between children's number abilities and their knowledge, understanding and skills in the spatial organisation strand of pattern-making. While number abilities may have little impact on the earliest stages of spatial organisation, they may contribute to the spatial pattern-making competencies demonstrated by the most advanced group of children at 4½ years.

There seems also to be an early and strong association between the abilities involved in early mark-making and the spatial organisation strand of pegboard work. The convincing association of spatial organisation and drawing abilities at 3½ years appears to be considerably weakened at 4½ years. It seems likely that, while figurative drawing and spatial pattern-making may have similar origins in early forms of mark-making with different media, the development of figure drawing and spatial pattern-making proceeds along increasingly different paths. Analysis of the case study material in this area, again beyond the bounds of this thesis, would be useful in further elucidating the nature of this changing relationship.

The analysis of the results relating to spatial organisation provides a contrast with the analysis of results relating to colour organisation. For colour organisation, the relatively consistent picture of results across time, with the findings of high levels of association, suggests

that there may be a generalised single factor such as general intelligence, impacting on the development of pattern related competencies. In contrast the spatial organisation strand of pattern-making seems to be associated with a more discrete set of abilities, primarily spatial in nature but with an increasing association with children's developing number and musical competencies.

GENDER

In addition to range of specific competencies considered above, in the analysis of individual differences in the development of children's knowledge, understanding and skills in pattern-making, gender was considered as a potentially significant dimension of difference.

Boxplots

To compare children's knowledge, understanding and skills in the colour and spatial organisation strands of pattern-making by gender, an exploratory data analysis technique was used. Boxplots were used to explore the distribution of the levels of colour and spatial organisation achieved by boys and girls at both 3½ and 4½ years.



Figure 7.1 Boxplot for colour organisation levels by gender at 3½ years

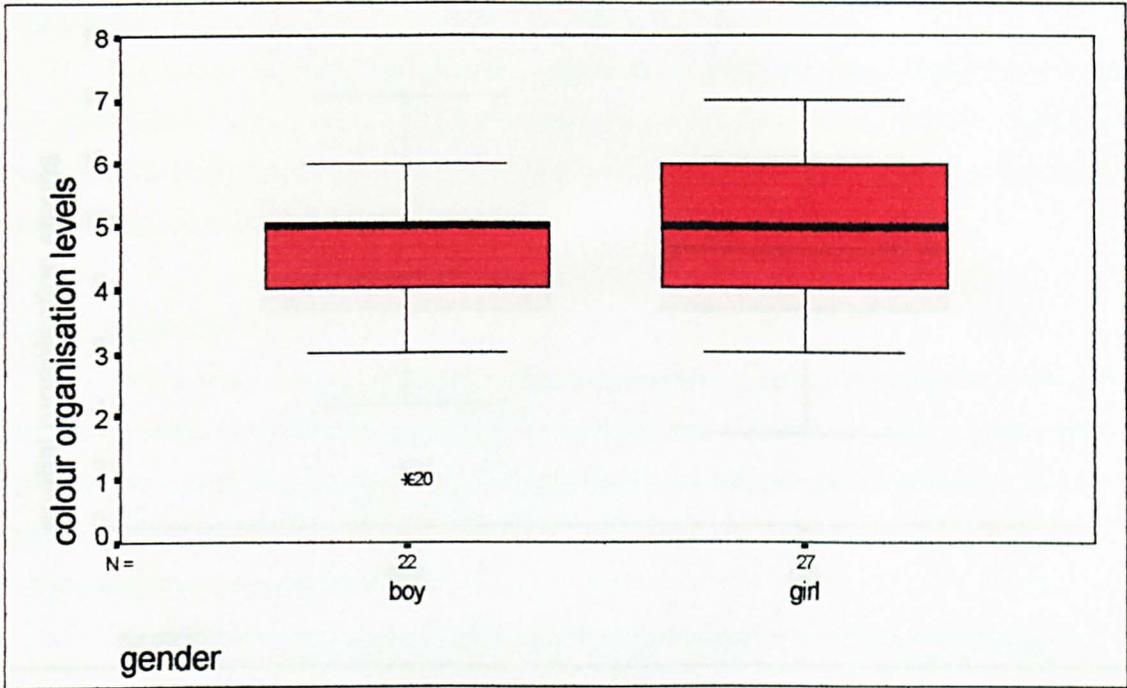


Figure 7.2 Boxplot for colour organisation levels by gender at 4½ years

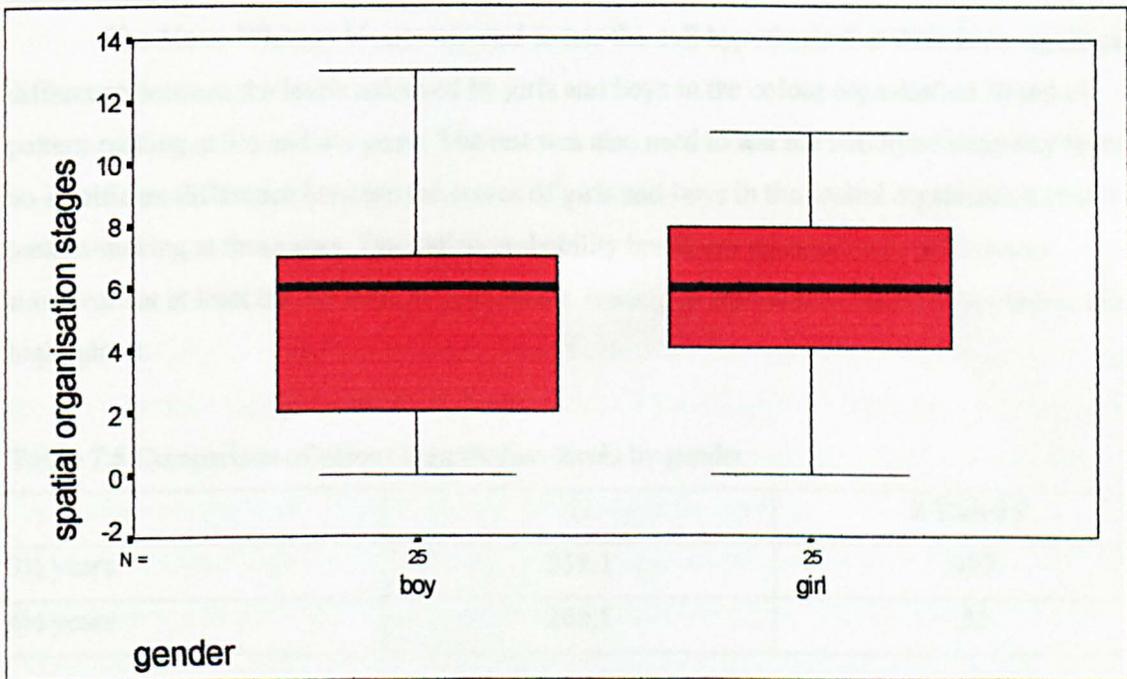


Figure 7.3 Boxplot for spatial organisation stages by gender at 3½ years

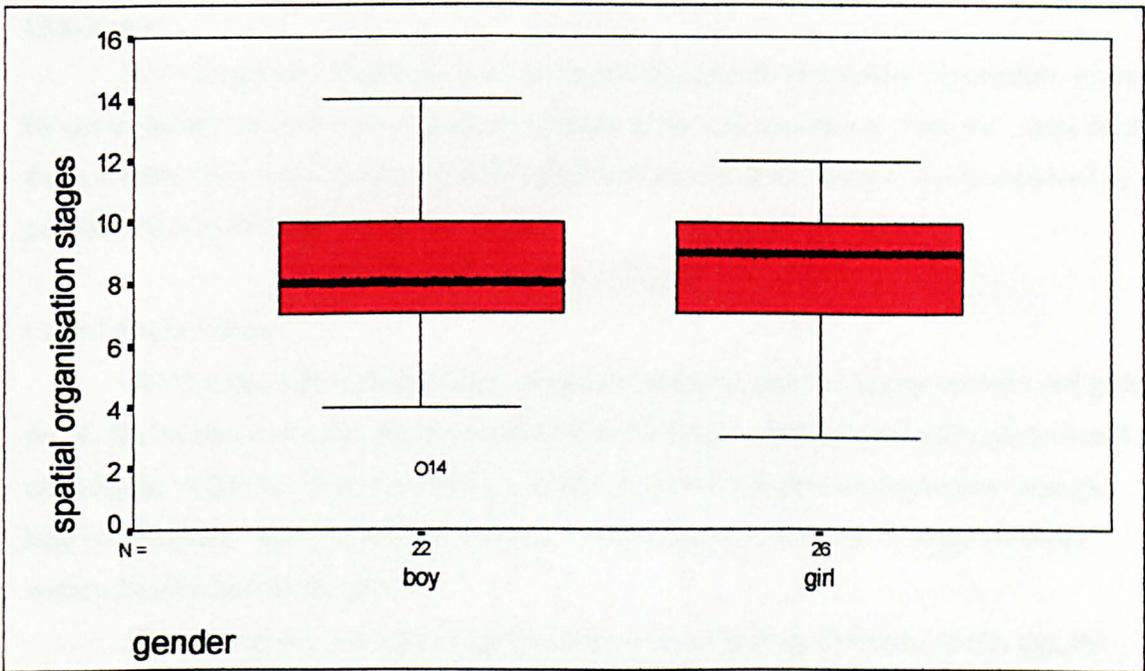


Figure 7.4 Boxplot for spatial organisation stages by gender at 4½ years

Statistical Tests

The Mann-Whitney U test was used to test the null hypothesis that there is no significant difference between the levels achieved by girls and boys in the colour organisation strand of pattern-making at 3½ and 4½ years. The test was also used to test the null hypothesis that there is no significant difference between the scores of girls and boys in the spatial organisation strand of pattern-making at these ages. Two tailed probability levels are reported. Any differences significant at at least the .05 level of probability, leading to rejection of the null hypothesis, are highlighted.

Table 7.5 Comparison of colour organisation levels by gender

	U	2 Tailed P
3½ years	271.1	.407
4½ years	266.5	.52

Table 7.6 Comparison of spatial organisation levels by gender

	U	2 Tailed P
3½ years	275.5	.467
4½ years	261.5	.607

Discussion

In a comparison of children's colour organisation levels and spatial organisation scores by gender there is no evidence to support rejection of the null hypothesis. However, analysis of the box plots show some interesting differences between the distribution of levels achieved by girls and boys at each age.

Colour Organisation

At 3½ years, although the boxes comprising the inter-quartile ranges for boys and girls match, the median score for girls is 1 level higher. However, whiskers on the box plots extend up to higher values for boys than for girls. Additionally the box plot for boys shows a single high value outlier. The boxplot demonstrates that the values for boys at 3½ years are more widely distributed than for girls.

The distribution of scores for girls and boys at 4½ years is different. At this age, the boy's median score increases from below to equal that of the girls. However, whiskers on the box plots now extend up to higher values for girls than for boys. Additionally there is one low outlier score for the boys. Girls appear to be slightly ahead in terms of the colour organisation strand of pattern-making by 4½ years but this is not a statistically significant difference.

Spatial Organisation

At 3½ years, although the median values for girls and boys match, the box comprising the inter-quartile ranges for girls is slightly higher than that for boys. However, as with the boxplot for colour organisation at 3½ years, whiskers on the boxplots extend up to higher values for boys than for girls.

The distribution of scores for girls and boys at 4½ years is slightly different. At this age, the girl's median score increases from equal to above that of the boys. However, as at 3½ years, whiskers on the box plots extend up to higher values for boys than girls. Again, as with colour organisation values at 4½, there is one low outlier value for the boys.

The statistics do not demonstrate significant gender differences in children's knowledge, understanding and skills in the colour or spatial organisation strand of pattern-making at either 3½ or 4½ years. However, the boxplots demonstrate how boys' scores are more widely distributed in both colour and spatial organisation strands of pattern-making at 3½ years and in the spatial organisation strand at 4½ years. There may be small gender effects that are masked by the process of statistical analysis. This seems to be most likely for spatial organisation, where small numbers of boys achieve at the highest levels at both 3½ and 4½ years.

Conclusion

Chapter 7 has considered the relationship between firstly, children's knowledge, understanding and skills in two key strands of pattern-making and secondly, some potentially

significant areas of developing cognition. This chapter has also examined the relationship between children's knowledge, understanding and skills in pattern-making and children's gender. The analysis has drawn on quantitative data only.

There are no significant findings for gender. However, an exploratory approach to data analysis does highlight interesting differences in the distribution of levels or scores achieved by girls and boys. The findings for gender differences are complex and this remains an area that would support further study.

There are findings of significant associations between some key areas of developing cognition and children's knowledge, understanding and skills in pattern-making. There are clear associations with the colour organisation strand of pattern-making, and these are wide-ranging for children at 4½ years. There is a less clear set of associations for spatial organisation. In contrast to the colour organisation strand of pattern-making, the spatial organisation strand seems to be associated with a relatively narrow set of abilities. These abilities are primarily spatial in nature. In both cases, there is the potential to illuminate some ways in which these associations may work through an examination of qualitative case-study data.

However, this is beyond the bounds of the present study. It would be a valuable area for future research. This and other directions for future research are considered in the next chapter, Chapter 8, following a summary and evaluation of the main findings of this study..

CHAPTER 8

CONCLUSIONS

The main study findings have been presented in detail in Chapters 5, 6 and 7. This final chapter presents the conclusions to the study. It begins with a summary of the study findings and then moves on to compare these findings with the findings of previous research. Differences in findings between this and earlier studies are identified and discussed. In particular, significant new findings arising from the study are highlighted.

Following on from the presentation of findings, there are evaluations of the study's effectiveness in answering the main research questions and achieving its broader aims. The study's limitations are reviewed and the implications of the study outlined. Finally, some valuable directions for future research are outlined.

SUMMARY OF MAIN FINDINGS

KNOWLEDGE, UNDERSTANDING AND SKILLS IN PATTERN-MAKING

This study set out to investigate young children's knowledge, understanding and skills in pattern-making at 3½ and 4½ years. Firstly, the study investigated children's knowledge, understanding and skills in repeated pattern-making. Secondly, it investigated knowledge understanding and skills in linear and 2D spatial pattern-making. Thirdly, it investigated children's pattern perception and understanding of the word 'pattern'.

Before summarising the main findings of the study, it is important to place limits on the appropriateness of generalising the findings beyond the sample studied. The sample for this study came from an inner-city school where a significant number of children experienced disadvantage across a range of indicators. Despite a full ability range, relatively high proportions of children were formally identified as children with special educational needs during their first year at school.

Repeated Pattern-making

3½ years

The first set of findings relates to children's knowledge, understanding and skills in copying, continuing and devising repeating patterns. The study presents limited positive findings for children at 3½ years. In this study, the majority of children evidence no knowledge, understanding or skills in copying, continuing or devising repeated patterns. However, a small group of children are successful in devising simple 2 unit repeated patterns in work with tiles following adult modeling of repeated pattern-making. The majority of successful children sustain their alternating sequences. Although invited to make their own pattern, at 3½ years most children reproduce the repeating pattern modeled by the adult.

The findings for other assessment contexts demonstrate three children continuing a repeated pattern and a single child devising a pattern with pegs. Just one child devised a complex pattern, a 5 unit repeating sequence made in work with pegs.

4½ years

The study findings for children at 4½ years are more positive than findings for children at 3½ years, even though it is still only a minority of the older group who evidence knowledge, understanding and skills in copying, continuing or devising repeating patterns. There are study findings of a significant association between children's age and their skills in copying, continuing or devising repeating patterns for six out of eight assessment contexts, indicating real growth from 3½ to 4½ years.

The findings for children at 4½ years are that approximately one third of children copy or continue 2 unit repeating patterns, with a majority of these children sustaining their patterns. Additionally, at 4½ years, about one fifth of children devise patterns. These children most commonly devise patterns in work with mosaic tiles, following modeled pattern-making. A small group of 4½ year olds make repeating patterns more complex than patterns made by children at 3½ years. Some of this group makes patterns with 3 or more units. Two children devise sequences of repeating patterns sustained across the lines of the pegboard.

At 4½ years, most successful children work with simple 2 unit repeating patterns and in only one or two contexts. However, by this age a significant minority of the sample copy, continue and devise repeating patterns across a number of contexts, demonstrating secure and flexible procedural knowledge and skills.

Linear and 2D Spatial Pattern-making

The second set of findings relates to children's knowledge, understanding and skills within the spatial organisation strand of pattern-making. These findings parallel the findings for repeated pattern-making. A small minority of children demonstrates a relatively restricted range of competencies at 3½ years. At 4½ years, a significant minority of children, about one quarter demonstrates knowledge, understanding and skills in 2D pattern-making. These children devise a wider range of patterns than children do at 3½ years. Again, there are study findings of a significant association between children's age and pattern-making competencies, indicating clear progress over the period.

Turning to the detail of study findings, linear symmetrical pattern-making seems to be an infrequently occurring feature of children's pattern-making at this age. This study finds just one child, at 4½ years, marking a line symmetrically in work with pegs.

However, 2D pattern-making is a more frequently occurring feature of children's work. Study findings are that children at 4½ years devise a wider range of spatial patterns than do children at 3½ years. A small minority of children at 3½ years devise 2D patterns by combining

two or more of five basic elements of pattern. By 4½ years approximately one quarter of children devise 2D patterns. While some use the same basic elements of pattern used by children at 3½ years, particularly non-linear basic elements, the 4½ year olds make increased use of the elements of complex linear organisation..

Co-ordinated Colour Organisation and Spatial Pattern-making

The third set of findings relates to children's knowledge, understanding and skills in co-ordinating two key strands of pattern-making, colour and spatial organisation. The study presents limited positive findings for the age group studied. A single 3½ year old and a small group of 4½ year olds co-ordinate 2D colour organisation with symmetrical pattern-making. With such small numbers of children evidencing competencies, the findings do not demonstrate a convincing association between age and children's skills in this area.

Pattern Perception and Children's Understanding of the Word 'Pattern'

3½ years

The study presents limited positive findings of pattern perception for children at 3½ years. In the assessment of pattern perception, just three children evidence an implicit awareness of one key feature of pattern. Additionally, many children at 3½ years respond to the adult's use of the word 'pattern' as if it were an unfamiliar word. Some of these children use the word in repeating pattern contexts in an apparent attempt to test out its meaning. Children most frequently hypothesise the meaning of 'pattern' as a colour word.

However, a small group of 3½ year olds do evidence a developing and appropriate understanding of the word 'pattern' in response to adult use of the word in a repeated pattern-making context. Additionally, three children use the word in reference to pegboard configurations. One child makes explicit reference to a personal understanding of pattern as a sequence of several different colours.

The findings relating to children at 4½ years are similar. Again, there is little positive evidence of pattern perception, with just one child making explicit reference to the organisation of colours within a pattern. However, at 4½ years, an increased group of four children evidences an explicit and unconventional understanding of pattern as a sequence of several different colours.

In conclusion, there are study findings of significant increases in the range of pattern-making skills and procedural knowledge for children at 4½ years as compared to children at 3½ years. However, significant increases in pattern-making skills and procedural knowledge are not paralleled by increases in pattern perception or in children's understanding of the word 'pattern'.

THE DEVELOPMENT OF KNOWLEDGE, UNDERSTANDING AND SKILLS IN PATTERN-MAKING

As well as investigating the knowledge, understanding and skills in pattern-making of young children at 3½ and 4½ years, this study set out to investigate children's development in this area over the period of a year. It set out to identify the earliest stages in children's development as well as key markers along a developmental pathway towards pattern-making competencies. In the language of the Curriculum Guidance for the Foundation Stage (2000), it set out to identify 'stepping stones' towards and within repeated pattern-making and towards and within spatial pattern-making. It also set out to identify 'stepping stones' in terms of children's declarative knowledge of pattern and their understandings of the word 'pattern'. This resulted in a study focus on commonalities in development.

However, as well as focusing on commonalities the study set out to detail individual differences in the pathways followed by children in their development towards and within pattern-making. Additionally, it set out to identify individual differences in the nature of children's knowledge, understanding and skills in pattern-making and in rates of development.

The study findings relating to children's development are complex. It is important to note that some of the rich complexity of individual development, captured in qualitative data, is lost in the process of generalising findings.

The Development of Repeated Pattern-making

Case study findings

There are findings of commonalities as well as findings of significant differences in children's development of knowledge, understanding and skills in repeated pattern-making between 3½ and 4½ years.

The seven case studies reported exemplify children's relatively similar starting points in terms of the colour organisation strand of pattern-making at 3½ years of age. There are just small variations. For example, some children demonstrate no initial interest in colour organisation. Others demonstrate just an early interest in colour naming or in grouping pairs of components by colour. By 4½ years, all but one of the seven children copy, continue or devise repeating patterns in at least one context. There are, however, findings of an increase in the diversity of children's work across contexts.

Despite the differences in children's achievements at 4½ years, the case studies evidence many or most children passing common milestones on pathways towards repeated pattern-making. They also evidence common milestones for the minority of children who progress towards complex repeated pattern-making.

An hypothesised developmental pathway

The study presents an hypothesised developmental pathway towards and within repeated pattern-making. The pathway is complex, with seven levels, and from Level 4 onwards

it includes 2D as well as linear work. This hypothesised pathway for the colour organisation strand of pattern-making is presented in detail in Appendix 5.

Quantitative Findings

The quantitative strand of the study provides support for key aspects of the hypothesised pathway for colour organisation leading towards and within repeated pattern-making. The support, however, is qualified. In particular, there is little evidence to support the position of Level 2 as a distinct level within the hypothesised pathway. Additionally, although Levels 6 and 7 are supported by the quantitative analysis, these levels remain tentative. This is because only small numbers of children worked at this level during the study.

Individual differences in development

There are study findings of commonalities in development towards and within repeated pattern-making. Additionally, there are findings of significant differences, with the pathways followed by individual children more distinctive than any generalised pathway can allow.

While a minority of children progress steadily through the levels of the pathway, many children show uneven development over the year. Additionally, development is not solely marked by children's progression through pathway levels. Firstly, many children evidence development by working at a particular level in a new context or in an increased range of contexts. Secondly, some children demonstrate development within a level as they began to work in more sustained ways. Thirdly, some children demonstrate development as they progress from copying a model or modeled pattern to devising their own sequences or patterns.

The study findings relating to developmental distinctions between copying and devising suggest that the route from copying to devising is common but it is not invariable. Children seem to vary in their motivation to devise sequences and patterns. Individual differences in creativity are not directly related to children's levels of working. Some children appear to be strongly motivated to explore an individual theme in pattern-making in a self-directed way, while others are more motivated to follow the lead of the adult.

There are additional findings of wide variation in children's rates of development over the year of the study. One child evidences no progress in the colour organisation strand of pattern-making and a small group evidence progress just within one level. The progress of other children through the levels of the hypothesised pathway varies from one to four levels.

Development Towards and Within Spatial Pattern-Making

Case study findings

The study findings are of greater diversity in children's starting points for spatial organisation than for colour organisation. The representative case studies exemplify children's varied starting points at 3½ years in the spatial organisation strand of pattern-making.

Additionally, there are findings of significant variation in the complexity of spatial organisation achieved by children at 4½ years.

However, all case study children evidence some development in the spatial organisation strand of pattern-making over the year of the study. For example, by 4½ years, five of six case study children use at least one basic element of pattern. All show competence in basic linear organisation and are at least beginning to move beyond this, repeating or connecting two or more lines.

Despite significant differences in children's starting points and in their achievements at 4½ years, the case studies highlight many similarities in children's development within the spatial organisation strand of pattern-making. They evidence children passing a number of common milestones on pathways towards basic linear organisation. Additionally the case studies evidence several children developing control of some basic elements of pattern over the year of the study. A significant minority of children progress beyond this. There are further commonalities in children's development towards complex linear organisation.

An hypothesised developmental pathway

The study presents hypothesised developmental pathways to basic linear organisation and, leading beyond this, to complex spatial organisation. It also presents short hypothesised pathways to the basic elements of pattern. These pathways are outlined in Tables 6.9, 6.10, 6.11, 6.12 and 6.13.

Children's 2D pattern-making, as defined by this study, incorporates two or more basic elements of pattern or elements of complex linear organisation. Patterns can include linear and/or non-linear basic elements of pattern. Although the study presents hypothesised pathways within the spatial organisation strand of pattern-making, it does not present an hypothesised developmental pathway to 2D pattern-making. This is because study children devise their first 2D patterns at different stages of development in terms of the outlined pathways.

The quantitative strand of the study provides some qualified support for the broad outlines of hypothesised developmental pathways within the spatial organisation strand of pattern-making. However, the complexity of data relating to the spatial organisation strand of pattern-making places limits on the use of quantitative approaches to data analysis. Therefore quantitative findings provide qualified support for the broad outlines but not the detail of hypothesised development.

Individual differences in development

As well as commonalities in development, the findings highlight individual differences in children's development within the spatial organisation strand of pattern-making. As with colour organisation, the pathways followed by individual children are more distinctive than any generalised pathway can allow.

Development for many children appears to be uneven over the year, with only a minority of children progressing steadily through each assessment period. There is also a marked variation in children's motivation to explore spatial forms and to devise spatial patterns. In particular, children vary in terms of their interest in the basic elements of pattern. Some children progress towards complex linear organisation but show no interest in these basic elements. For a small number of children, relatively low motivation to explore spatially seems to be related to a predominant interest in the colour organisation strand of pattern-making.

The Development of Pattern Perception and Children's Understanding of the Word 'Pattern'

Turning to the development of pattern perception and children's understanding of the word 'pattern', the study findings are relatively limited. The majority of children evidence no progress or limited progress in terms of pattern perception or understanding of the word 'pattern'. Additionally, children's development in this area seems to be markedly individualist.

There are no study findings of development in children's perception of colour organisation within linear patterns. A small minority of children evidences an early interest in the meaning of the word 'pattern.' Others demonstrate an emergent understanding of pattern as a sequence of different and aesthetically pleasing colours. However, the study cannot confirm these as two steps in an early developmental sequence.

Some children use representational language to talk about spatial configurations throughout the study. Other children make reference to the mathematical features of their work, particularly shape. There is just one example of a case study child identifying a spatial pattern as a pattern. The study cannot, however confirm a sequence for children's developing understanding of the word 'pattern' in relation to spatial patterns.

DEVELOPMENT IN PATTERN: A RELATIONSHIP WITH OTHER DIMENSIONS OF DEVELOPMENT

Colour Organisation and Key Aspects of Cognitive Development

There are findings of clear associations between children's knowledge, understanding and skills in the colour organisation strand of pattern-making at 3½ years and the wider competencies of language, number and drawing, as well as colour matching and naming. Associations with spatial and rhythmic abilities are less convincing. At 4½ years, there are clear associations between colour organisation and all the areas of cognition reviewed. The findings are suggestive of a single factor, possibly general intelligence, having a generalised effect on scores.

Spatial Organisation and Key Aspects of Cognitive Development

In contrast, the study findings for associations between spatial organisation and key areas of cognitive development are complex. The spatial organisation strand of pattern-making seems to be associated at both ages with a discrete set of abilities that are primarily spatial in nature. However, at 4½ years, there is an increased association between spatial organisation and children's developing musical and number competencies.

Gender

There are no findings of significant gender differences in children's knowledge, understanding and skills in either the colour organisation strand or the spatial organisation strand of pattern-making. However, at each age, there are some differences in the distribution of levels achieved by girls and boys. At 3½ years, the boys' scores are more widely distributed in both strands of pattern-making. At 4½ years they are more widely distributed in the spatial organisation strand only. While there are no significant differences for girls and boys, there may be small gender effects that are masked by the process of statistical analysis.

COMPARISON WITH PREVIOUS FINDINGS

The findings of this study have been compared with the findings of previous studies as reviewed in Chapter 2. Where a direct comparison of findings is possible, the comparison is reported in this section of the chapter. New findings are then revisited in the section of the chapter that highlights the achievements of the study. However, in some cases there are no previous findings relating to the present study, and so comparisons are not possible. In this case the new findings are reported in the section highlighting achievements.

KNOWLEDGE, UNDERSTANDING AND SKILLS IN PATTERN-MAKING

Repeated Pattern-Making

3½ years

This study confirms the findings of earlier studies that few 3½ year olds successfully copy, continue or devise repeating patterns. However, it presents a new finding relating to the developing competencies of three year olds, identifying a context where nearly one fifth of three year olds successfully copy a 2 unit repeating pattern. The context is that of devising a pattern with mosaic tiles following adult modeling. One earlier study, the Agam action research project (Hershkowitz and Markovits 1992), presents similarly positive findings for children's responses to adult modeled pattern-making. However, the Agam study uses different play materials and study children are trained to memorise the modeled sequences.

4½ years

Earlier studies report that many but not all children copy and/or continue repeating patterns by the time of entry to a reception class at from 4½ to 5 years of age or at five years. This study, focusing on children at 4½ years, is less positive in its findings, with only one third of children copying or continuing patterns. The less positive findings for copying and continuing at 4½ years may relate to the skewed nature of the sample.

The findings for children devising patterns at 4½, however, are more positive than the most comparable recent research (Aubrey 1993). Aubrey's findings are that no children of this age devise repeating patterns. However, the findings of this study are that approximately one fifth of children devise patterns and some children devise relatively complex patterns. Only the Agam action research project, with its intensive educational programme, reports more positive findings.

It seems likely that this study facilitated the advanced children's demonstration of devising competencies through its focus on children making patterns in ecologically valid contexts. Additionally, as at 3½ years, features of the Mosaic Tiles assessment context may have impacted on children's competencies. This issue of context is discussed further in the section on directions for further research.

Linear and 2D Spatial Pattern-making

A small number of earlier studies (Kellogg 1964; Fenson 1985; Athey 1990) focus on young children combining marks, lines and shapes as patterned configurations in artwork. Some focus on children's arrangements of blocks (Goodson 1982; Reifel and Greenfield; Gura 1992). These studies include 3 and/or 4 year olds. They do not, however, focus directly on or attempt to quantify those children devising symmetrical linear patterns or 2D patterns at specific ages. As a result it is difficult to compare these studies with the present study.

Booth's (1981) study is the one study that is comparable to the present one in terms of its key focus on young children making 2D patterns. However there are three important differences between the studies. Firstly, Booth's study focuses on children working with paint in contrast to pegs and pegboards. Secondly, the age group studied by Booth is the older group of 5 and 6 year olds. Thirdly, Booth's definition of pattern is less demanding than the definition used in this study. Booth includes, as an example of pattern, one configuration that commonly occurs in the present study but is not categorised as a pattern. It is instead identified as an element of complex linear organisation.

Because of these differences, it is not possible to make direct comparisons with the findings of earlier work. However, this study does confirm and extend aspects of some earlier research. In particular it confirms findings of specific patterned configurations in the artwork of children at 3 and 4 years of age. It also confirms findings of specific patterned configurations in Booth's study of older children. Some elements of complex linear organisation and some

patterns made by young children in this study match the less advanced translation patterns and reflection patterns identified in Booth's study.

However, a significant difference in findings is that the present study finds patterned configurations in a much younger age group than Booth. This difference in findings may relate in part to the relatively controllable nature of pegs as a medium for pattern-making, as compared to paint.

THE DEVELOPMENT OF KNOWLEDGE, UNDERSTANDING AND SKILLS IN PATTERN-MAKING

The Development of Repeated Pattern-making

The findings of this study confirm some findings from earlier research focused on development towards and within repeated pattern-making. This study, like Rustigian's (1976), identifies children's apparently random choice of elements as the first stage of a developmental sequence. Like several earlier studies (Frith 1970; Rustigian 1976; Threlfall 1999) the repetition of a single element is identified as the second stage in the developmental sequence. This study also confirms Rustigian's third stage, with its focus on relationships of similarity and difference. However, this study fails to confirm Rustigian's fourth stage for pattern continuation tasks. There are no findings of children reproducing pattern sequences in reverse order in similar activities.

This study also confirms earlier findings (Stenberg 1974) of developmental distinctions relating to the number of elements in a sequence. Study findings are that repeating sequences with 3+ units follow on from simple alternating sequences. These findings however remain tentative due to the small numbers of children working at this level in the present study.

Focusing on a different strand of complex repeated pattern-making, Pieraut Le-Bonniec's (1983) study finds another developmental sequence within 2D pattern-making. In this sequence, mastery of the inversion of an alternation is followed by mastery of a cyclic structure of alternating sequences, an advanced level of pattern-making achieved by some 5 and 6 year olds only. This study provides limited confirmation of these findings, with one child at 4½ years sustaining the cyclic structure of alternating sequences through six lines of a pegboard.

Development Towards and Within Spatial Pattern-making

In the spatial organisation strand of pattern-making, there are again difficulties in comparing the findings of this study with the findings of earlier ones, due to a range of differences in research design. However, this study does confirm the main outlines of the developmental sequences reported by Athey (1990), Booth (1984) and Fenson (1985). There are many similarities in children's developing mastery of spatial organisation across the media used in the different studies.

However, the medium of pegs and pegboard does support development towards particular forms of spatial organisation and pattern-making that are not found or highlighted in the earlier studies. These are outlined as new findings below.

DEVELOPMENT IN PATTERN: A RELATIONSHIP WITH OTHER DIMENSIONS OF DEVELOPMENT

Gender

Earlier research, reviewed by Nickson (1999), finds small gender differences in young children's work with poleidoblocs. Firstly, there are differences in the kinds of structures made by girls and boys. Secondly, girls pay more attention to colour than boys.

In contrast, the present study has no findings of gender related differences in the kinds of configurations made by children. The findings of small but not significant gender differences in spatial organisation relate to levels of working only. The present study findings, however, are suggestive of a slight advantage for girls in the colour organisation strand of pattern-making, although the differences again are not statistically significant.

NEW FINDINGS

This section highlights the significant new findings from this study, including findings that have been identified in the earlier comparison of present and previous findings.

KNOWLEDGE, UNDERSTANDING AND SKILLS IN PATTERN-MAKING

Repeated Pattern-making

This study presents positive new findings relating to the knowledge, understanding and skills of young children in the colour organisation strand of pattern-making. Firstly, a significant minority of three year olds demonstrate competence in copying a 2 unit repeating pattern. This finding is for a specific assessment context only, pattern-making with mosaic tiles following adult modeling. This context is different to the contexts used for copying in earlier studies,

Secondly, the findings for children devising patterns at 4½ years are more positive than the mainly negative findings of earlier studies. The only previous study to acknowledge the creativity of many four year olds in devising repeating patterns is the Agam action research project. In the present study findings, one fifth of children devise repeating patterns and several children devise relatively complex patterns, including 3+ unit patterns and 2D sequences of repeating patterns.

Linear and 2D Spatial Pattern-making

This study presents new findings relating to the knowledge, understanding and skills of 3 and 4 year olds in linear and 2D spatial pattern-making. No earlier studies with this age group have focused on linear symmetrical pattern-making. However, new findings relating to this aspect of pattern-making are mainly negative. Linear symmetrical pattern-making is found to be an infrequently occurring feature of children's pattern-making for the age group studied.

The new findings relating to young children's knowledge, understanding and skills in 2D pattern-making are more positive. No previous studies have focused directly on this aspect of pattern-making with the 3 to 4 year old age group and no previous studies have reported on 2D pattern-making using the medium of pegs and pegboard.

This study finds that a small minority of children at 3½ years and approximately one quarter of children at 4½ years devise 2D patterns in work with pegs and it details the spatial elements that these young children use to construct their 2D patterns. These new findings highlight young children's creativity.

Co-ordinated Colour Organisation and Spatial Pattern-making

No earlier studies, except Booth's (1984) study of 5 and 6 year olds, have focused on young children's co-ordination of colour and spatial organisation in 2D pattern-making. Booth's study focuses closely on the geometric properties of 2D patterns, while giving only limited attention to children's use of colour in the stages prior to geometric pattern-making. This study presents positive findings relating to a younger age group, with a single child at 3½ years and a small group of children at 4½ years creatively co-ordinating colour and spatial organisation

Pattern Perception and Children's Understanding of the Word 'Pattern.'

Study findings relating to children's pattern perception and understanding of the word 'pattern' at 3½ and 4½ years are new. A previous study in this area (Rawson 1993) includes a child of 4 years 11 months as its youngest subject. The new findings emphasise most children's limited competencies in this area. Nevertheless, the study does present evidence of some children attempting to make sense of the word 'pattern' and some children articulating personal understandings of the word.

THE DEVELOPMENT OF KNOWLEDGE, UNDERSTANDING AND SKILLS IN PATTERN-MAKING

Colour Organisation

Study findings relating to the stages of the developmental pathway to linear repeated pattern-making largely confirm the findings of earlier studies. However, the study is new in its findings relating to 2D developments within the colour organisation strand of pattern-making.

Pieraut Le-Bonniec's (1982) findings relate to a developmental pathway for 2D colour organisation at an advanced level only. This study presents a developmental pathway for 2D colour organisation that leads into this advanced level of working.

Spatial Organisation

This study presents new findings relating to children's development within the spatial organisation strand of pattern-making. The new findings are in part a result of this study's use of pegs and pegboards as a medium, in contrast to the focus on graphic media or blocks in earlier studies. Athey's (1990) study reports children working with a wide range of media but it does not include findings for work with pegs and pegboard.

Pegs and pegboard as a medium makes possible a very detailed analysis of developmental pathways within the spatial organisation strand of pattern-making. This study consequently presents a level of detail in findings, not present in earlier studies. The medium is also less open-ended than other media. The square pegboard with its 10 x 10 grid offers some structuring for children at particular stages of development and it highlights some features of pattern in a way that is not evident with other media. As a result, some findings relating to children's development within the spatial organistaion strand of pattern-making are new.

Findings of an initial pathway to basic linear organisation and a pathway beyond this to complex linear organisation confirm some findings of earlier studies but present a level of detail not evident in these studies. The findings of pathways to some basic elements of pattern are also new.

The Development of Pattern Perception and Children's Understanding of the Word 'Pattern'

No earlier studies have focused on the development of pattern perception or developing understandings of the word 'pattern' for the 3 to 4 year old age group. Study findings of the seemingly limited and individualistic nature of children's development in this area are therefore new.

DEVELOPMENT IN PATTERN: A RELATIONSHIP WITH OTHER DIMENSIONS OF DEVELOPMENT

Pattern-Making and Key Aspects of Cognitive Development

The study findings relating to associations between key aspects of developing cognition and colour organisation are new, as are findings relating to associations with spatial organisation. No earlier research has examined young children's pattern-making competencies in this wider context. Findings demonstrate a convincing set of associations between colour organisation and a range of other measures, suggesting some form of general intelligence underlying the colour organisation strand of pattern-making. In contrast, the findings highlight a

narrower set of associations with spatial organisation. This suggests a more discrete set of abilities informing competencies in this area.

Gender

There are new findings relating to gender and children's knowledge, understanding and skills in the colour and spatial organisation strands of pattern-making at 3½ and 4½ years. Most previous research has focused on gender effects in the mathematical development of older children. The findings of this study are suggestive of small but contrasting gender effects in the two aspects of pattern-making. However, there are no findings of significant gender related differences.

ACHIEVEMENT OF AIMS

I embarked on this study in order to explore more deeply a long-term professional interest in young children's creativity and their mathematical learning. The study was framed within a context of recurring and imposed curriculum change for schools and more recently imposed curriculum change across a range of early years settings.

I selected pattern as the focus of the study for a number of reasons. Firstly, pattern has been acknowledged as central to mathematics education in recent accounts (Fletcher: 1970). Secondly, pattern-making has been a key strand of the early years mathematics curriculum, supporting both mathematical learning and children's creativity for several decades (The Nuffield Foundation 1967). Thirdly, approaches to pattern have been subject to many changes in recent early years curricula, with change not clearly linked to research findings. Fourthly and closely related to this, children's early work with pattern has been relatively neglected in the research literature.

The broad aims of the study were firstly, to evaluate the research base underpinning recent changes to the focus on pattern within early years mathematics curriculum and secondly, to inform the knowledge base for any future reformulation of curriculum goals and guidance. To inform this knowledge base, the broad focus on pattern was refined as a set of specific research questions.

The study has been successful in answering the specific research questions and therefore successful in achieving its broader aims. There is some confirmation of earlier findings. Additionally, there is a wide range of new and complex findings relating firstly, to young children's knowledge, understanding and skills in two key strands of pattern-making; secondly, new findings relating to the development of knowledge, understanding and skills in pattern-making; and thirdly, new findings relating to individual differences in development. These findings have some important implications. There are implications for the pattern-related

curriculum goals in the early years mathematics curriculum and implications for learning and teaching. The implications of the study are considered below.

However, while acknowledging the success of the study, it is important to acknowledge some limitations. Before moving on to a consideration of implications, it is important to clarify the nature and extent of these limitations.

LIMITATIONS OF THE STUDY

There are clear limits to the study in terms of the appropriateness of generalising findings. Firstly, despite a full ability range, the study sample was weighted at the lower end of the range. Additionally, the sample included a high proportion of children formally identified during their first year at school as children with special educational needs. Study findings may therefore underestimate the knowledge, understanding and skills of the general population of nursery children.

Secondly, the relatively small size of the sample, particularly the sample for the longitudinal study, places further limits on the appropriateness of generalising findings. These limitations are particularly marked in relation to the kinds of knowledge, understanding and skills demonstrated by children at the higher levels of the developmental pathways. At these levels, hypothesised pathways must remain tentative.

Thirdly, generalising of findings is problematic because of the possible training effects introduced into the study by some assessment activities. Effects are most likely for the children in the longitudinal study who undertook four sets of activities over the year. In particular, the repeated adult modeling of pattern-making in Mosaic Tiles 2 may have led to improved performance for some children. This activity seemed to be supportive for many children. However, the effects of context were not fully investigated by the study. More generally, the high focus on pattern-making in the nursery over the period of the pilot and main studies may have shaped findings.

Because of these limitations, some study findings remain tentative. Some findings are both tentative and complex. As a result, many findings would provide valuable starting points for future research and these are considered at the end of the chapter.

IMPLICATIONS

Despite some limitations on generalising findings and the complexity of some findings, the study has clear implications for the place of pattern and pattern-related goals in a Foundation Stage mathematics curriculum. The present pattern-related early learning goal is for children to “talk about, recognise and recreate patterns” by the end of the reception year. This is a goal that

most children are expected to achieve by close to 5 or 6 years of age, depending on the child's month of birth.

Study findings for the 3½ to 4½ year old age groups suggest that the goal may not be well matched to children's developing mathematical knowledge, understanding and skills. The goal may in different ways overestimate and underestimate children's pattern-related competencies. There are implications firstly, for a future review of the early learning goals and guidance and secondly, for practitioners working with the present documentation.

Recognising and Talking About Patterns

The early learning goal

Study findings suggest that the early learning goal may overestimate young children's competencies in recognising and talking about patterns. Firstly, findings are that the majority of children by 4½ years demonstrate no competencies or very limited competencies in either talking about patterns or in recognising simple, linear patterns based on colour. When invited to talk about repeated and symmetrical patterns, most children give no verbal explanations evidencing recognition of pattern features. In the context of pattern-making activities, a small group of children hypothesise the meaning of the word 'pattern' as a colour word and a very small group of children articulate personal understandings of pattern that are mainly related to colour organisation.

Similarly, only a small group of children use the word 'pattern' in the context of 2D spatial work, with many children focusing instead on the representational features of this work. A small number of children use some mathematical language to talk about 2D work.

This study has focused on children, at the upper end of its age range, who are from 4 to 18 months younger than children at the end of a reception year. However, it seems likely that the talk and pattern perception aspects of the early learning goal set unrealistically high expectations for the majority of children to achieve by the end of the Foundation Stage.

Implications for approaches to learning and teaching about pattern

Despite some limitations on generalising findings, the study has implications for approaches to learning and teaching about pattern in the Foundation Stage. Study findings suggest that it may be very useful for practitioners to plan a range of contexts for children to talk about pattern. Rich and varied opportunities for children to talk about the features of patterns are likely to support emergent abilities in this area. However, it should be recognised that procedural knowledge precedes declarative knowledge in this strand of early mathematics.

Recreating and Creating Patterns

The early learning goal

In contrast to the first aspects of the early learning goal, the 'recreating patterns' aspect

of the goal seems to set inappropriately low expectations for children at the end of the foundation stage. Although the National Numeracy Strategy guidance (NNS 1999) recognises the creativity of many young children in devising patterns, this creativity is neither acknowledged nor supported by the wording of the goal.

The findings of this study are that more children copy or continue than devise repeating patterns at 4½ years. However, a significant minority devises repeating patterns and some children devise complex patterns. Additionally, the route from copying to devising is not straightforward, with some children motivated to devise patterns in preference to copying patterns

The findings relating to 2D spatial pattern-making also highlight the creativity of many children in the age group studied, in contrast to the early learning goal. At 4½ years nearly one quarter of children successfully devise 2D spatial patterns and a small group of children coordinate both colour organisation and 2D spatial pattern-making. A majority of children evidence clear progress in the spatial organisation strand of pattern-making in self-directed work over the year of the study.

There seem to be clear implications here for a re-evaluation of the early learning goal for pattern, a re-evaluation that takes full account of children's mathematical creativity. The early learning goal, with its focus on children recreating patterns, sets inappropriately low expectations for the majority of children to achieve by the end of the Foundation Stage.

Implications for approaches to learning and teaching about pattern

The study has clear implications for practitioners in terms of their approaches to children's pattern-making in the Foundation Stage. There is evidence to suggest that adult modelling of repeating pattern-making supports some children in copying or devising repeated patterns. Modeling may be particularly supportive to children at particular stages of development. However, there is also evidence highlighting the creativity of many young children in both the colour and spatial organisation strands of pattern-making. Study findings highlight the self-directed nature of much early patterning play and pattern-making where children have access to appropriate resources and the attention of interested adults. It is important that approaches to teaching and learning support and value this creativity. A narrow teaching focus on children recreating model patterns could have negative consequences, undermining the self-directed early learning evidenced in this study.

DIRECTIONS FOR FUTURE RESEARCH

Some study findings relating to young children's knowledge, understanding and skills in pattern-making remain tentative. In some cases, the findings, while suggestive, are not statistically significant, for example the findings of gender related differences in children's pattern-making competencies. Some findings are both tentative and complex, for example the findings relating to the advanced levels of the hypothesised pathways for colour and spatial organisation. Study findings of this kind could provide valuable starting points for future research.

While some research questions were fully explored during the study, others were considered more briefly. These questions also merit further investigation. Finally, both the pilot and main studies raised questions relating to young children and pattern that were clearly beyond the scope of the study. These questions provide further directions for future research. Possible directions are considered more fully in the following discussion.

Contexts for Pattern-making

This study raises the issue of context as a significant feature, influencing children's demonstration of pattern-making competencies. The question of context was raised during the first pilot study but it was not a focus for investigation in the main study. However, main study findings identify one assessment context, Mosaics 2, as a particularly supportive context for young children working within the colour organisation strand of pattern-making.

A number of features of Mosaic Tiles 2 could account for its supportive effects, for example, the play materials or the modeled verbalisation of the colour sequence. However these have not been systematically examined in this study. A useful direction for future research would be to investigate the effects of small variations in task context on the demonstration of young children's pattern-making competencies. It would be particularly useful to investigate further the effects of adult modeling, with and without the use of language to highlight pattern features.

The role of peer support

The main study raised questions relating to the role of peer support in facilitating young children's pattern-making. During independent work children often worked alone or in parallel to others. However, case study data, not reported to date, also evidences children working in pairs or small groups during self-initiated play with pattern-making materials. On some occasions children talked to each other about their work. One small group of children decided on a common theme, using the same colours for their pegboard patterns.

This study has focused on early mathematical learning as a primarily individual activity. However much early learning takes place within the peer group. The role of peer support in

children's self-directed mathematical learning would provide an interesting direction for future research.

Competencies beyond 4½ years

Study findings relating to advanced levels of the hypothesised pathways for colour and spatial organisation remain tentative because only small numbers of children worked at these levels. Additionally, at 4½ years very small numbers of children evidenced pattern perception or abilities in talking about patterns.

It would be useful to track children's development in pattern-related knowledge, understanding and skills from 4½ years through to the end of the Foundation Stage. This would allow for confirmation of firstly, the advanced levels of the hypothesised pathways and secondly, children's relative difficulties in recognising and talking about patterns. Extending the research in this way would support further evaluation of the pattern-related early learning goal.

Pattern: the relationships with wider competencies

A valuable direction for future research would be further investigation of the relationship between early pattern-related competencies and wider competencies. Study findings demonstrate a clear association between children's knowledge, understanding and skills in the colour organisation strand of pattern-making and their competencies across most key areas of cognitive development reviewed at 3½ years. There are clear associations for all key areas at 4½ years. There are contrastive findings for the spatial organisation strand of pattern-making. At 3½ years, there are clear associations with a subset of primarily spatial competencies. This subset is extended to include number and rhythmic competencies at 4½ years.

The quantitative data, while highlighting these sets of associations, cannot illuminate the underlying processes that may link particular competencies. However, a qualitative analysis of case study data, including assessment data for the wider set of competencies, could support a deeper examination of these processes. This would be a profitable direction for further research.

Conclusion

This study has been successful in achieving its broader aims, contributing new underpinning knowledge to support an evaluation of approaches to pattern in the early years curriculum. Some of the knowledge about young children and pattern gained through this study is rich and complex knowledge, necessarily simplified through the process of generalising. Some of the knowledge gained remains tentative.

While finding many commonalities in early development, the study highlights the individualistic nature of the preoccupations that motivate young children as learners in two key strands of pattern-making. It evidences the mathematical creativity of children, both in early patterning play and in pattern-making. The study contributes to an optimistic picture of young

children's mathematical interests, their motivation as learners and their considerable achievements.

The study also, however, highlights some areas of relative weaknesses for young children in their work with pattern. In particular, it emphasises the difficulties that many young children experience in making explicit the understandings that they more successfully demonstrate in action. Additionally, the study evidences the widely differing mathematical achievements of young children at 4½ years, at the beginning of their mathematical school careers, and some variation in children's dispositions for learning.

It is hoped that this new and detailed knowledge about children's early development in the pattern strand of mathematics will inform any future reformulation of curriculum goals and guidance. In addition, it is hoped that the tentative nature of some findings and the many new questions raised by the study will prompt further investigations in this field.

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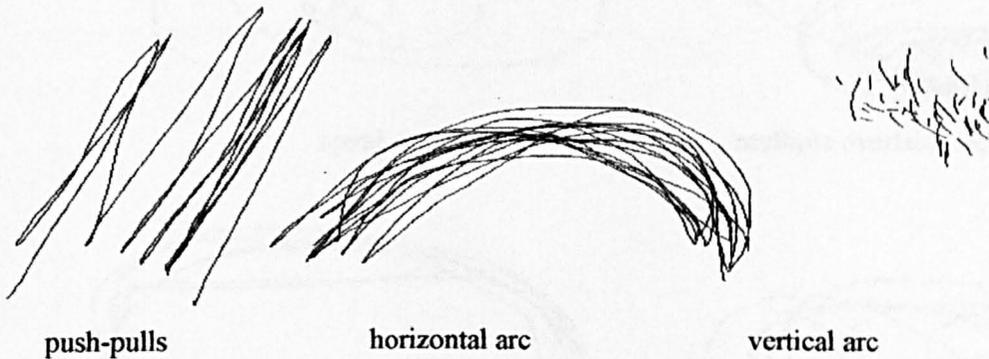
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APPENDIX 1**DRAWING ASSESSMENT**

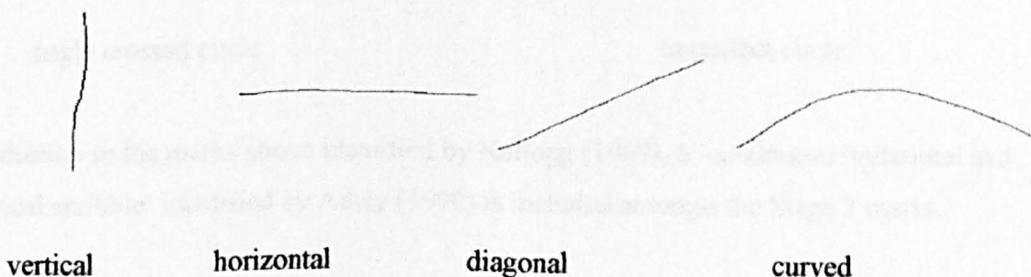
The scoring system for the drawing assessment was related to a devised sequence of developmental stages from early mark-making through to figurative drawing. The devised sequence of stages is presented below with reference to the supporting research evidence.

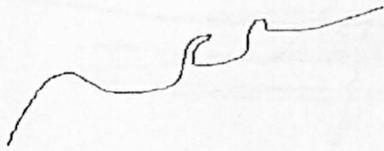
STAGE 1

Stage 1 comprises the three main groups of early actions proposed by Mathews (1993), resulting in three distinctive early marks. The first group of marks identified by Mathews are labelled 'push-pulls'. As the child's drawing hand moves to and from the body over the paper, a series of lines with acute angles is created. Mathews labels the second group of marks as 'horizontal arcs'. These marks are made as the child's drawing hand moves across the paper from side to side. The third group of marks is labelled 'vertical arcs,' comprising dots, dabs and short lines. Mathews describes how these marks are made as the child's hand stabs down onto the paper.

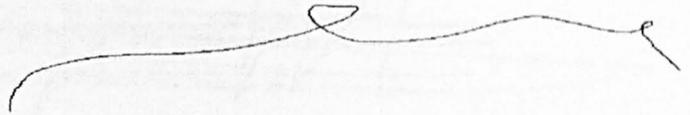
**STAGE 2**

Stage 2 comprises the marks that Mathews (1993) argues are gradually differentiated from the early actions described above, although he does not detail all of these. The differentiated marks of this second stage are detailed in the research literature amongst Kellogg's (1969) 'basic scribbles'.

Single Lines



roving open line



roving enclosed line



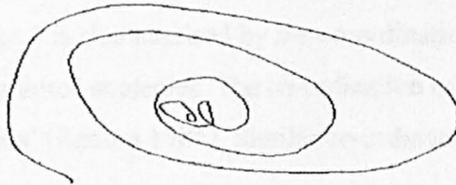
single loop line



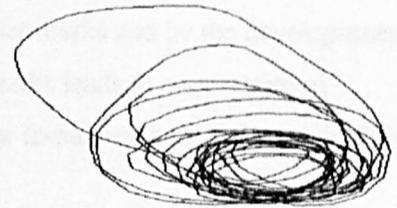
multiple loop line



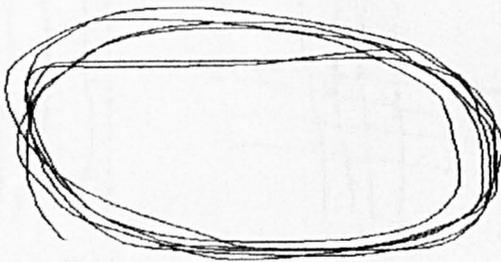
zigzag or waving line



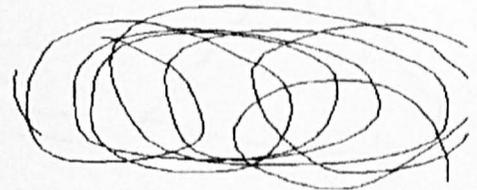
spiral



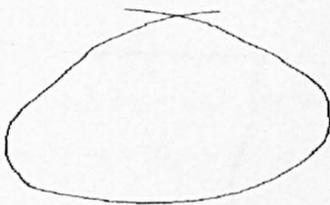
multiple overlaid circle



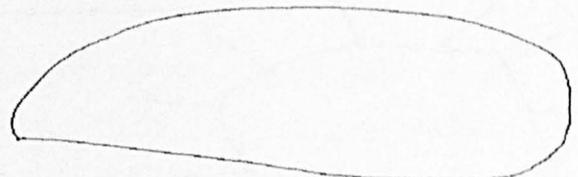
multiple circumference circle



circular line spread out



single crossed circle



imperfect circle

In addition to the marks above identified by Kellogg (1969), a 'continuous horizontal and vertical scribble' identified by Athey (1990) is included amongst the Stage 2 marks.

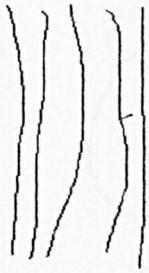


continuous horizontal and vertical scribble

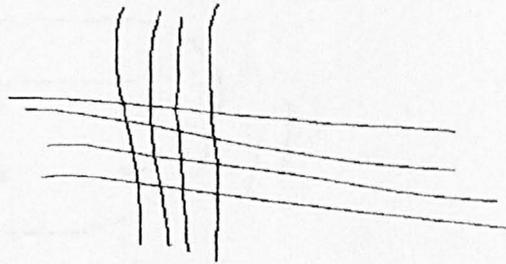
Children's drawings at Stage 2 are mainly pre-representational, with no expressed intention to represent. Some work can be described as 'fortuitous realism' (Cox 1992), as children begin to interpret their marks both during and after drawing. Representation may also be based on the action rather than the appearance of objects (Matthews 1993)

STAGE 3

Stage 3 is characterised by the co-ordination of earlier marks and by the development of new compositional strategies. The co-ordination of earlier marks leads to a repertoire of 'drawing units' (Fenson 1985). Similar co-ordinations can be found amongst Kellogg's (1969) complex forms.



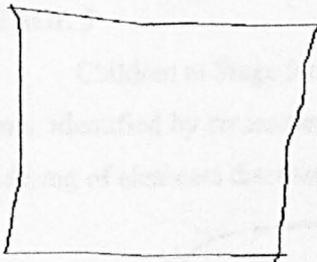
straight parallel lines



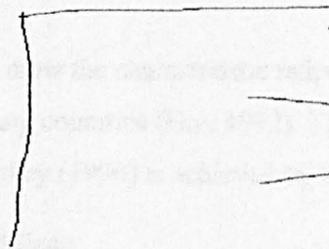
grid



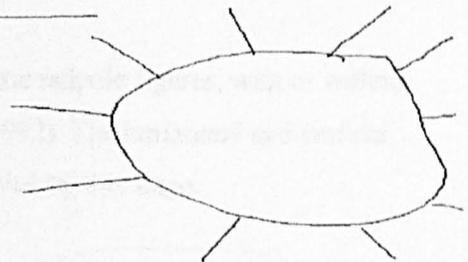
triangle



rectangle

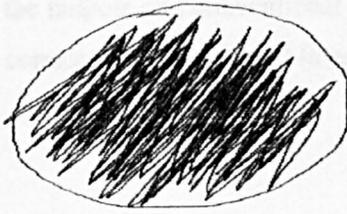


right



core and radial

The following are the compositional strategies (Fenson 1985) that first appear in Stage 3 drawings.



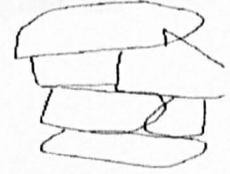
filling in



enclosure



partitioning

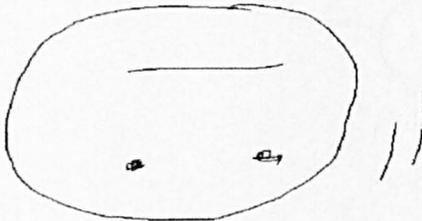


chunking

Many children at Stage 3 explore these new forms and strategies without any concern for representation. As at Stage 2, other children interpret their drawings as the work evolves.

STAGE 4

This transitional stage in development towards early figure drawing is identified by some but not all researchers. It seems likely that many children progress from Stage 3 to Stage 5. At Stage 4 children make their first intentional use of the drawing units and compositional strategies identified above in representational figure drawings. However, children working at this stage, while identifying some appropriate elements, for example legs, eyes and arms, do not consistently order the elements in their representations (Athey 1990).

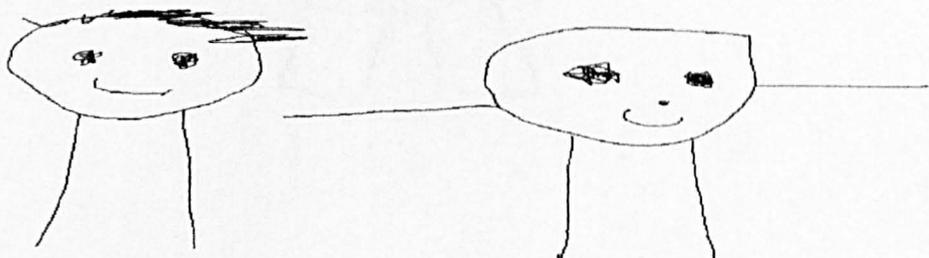


face with eyes and mouth

legs

STAGE 5

Children at Stage 5 children draw the characteristic tadpole figures, with or without arms, identified by researchers in many countries (Cox 1992). The horizontal and vertical ordering of elements discussed by Athey (1990) is achieved by this stage.



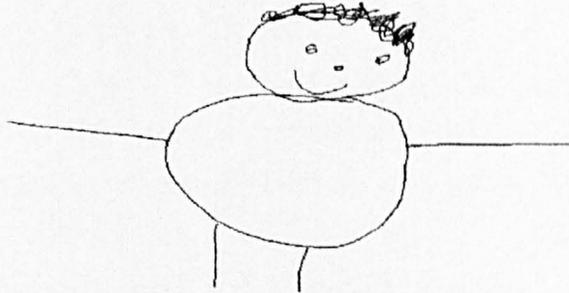
STAGE 6

Stage 6 is characterised by the figure that Cox (1992) describes as transitional between the tadpole and conventional forms. In this transitional form, lines representing arms are connected to the vertical lines representing an undifferentiated trunk and legs.



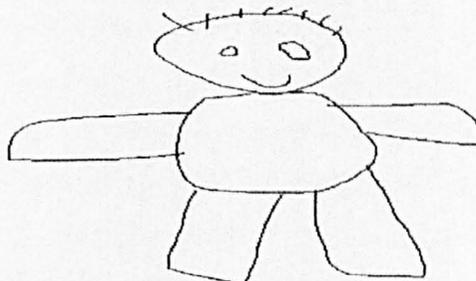
STAGE 7

Some children progress directly from Stage 5 to Stage 7, a stage characterised by a clearly differentiated trunk (Cox 1992). At Stage 7, children use separate graphic schema to represent at least six basic body parts, the head, the trunk, two arms and two legs. During this stage, children increasingly differentiate and add details to their figure drawings.



STAGE 8

Drawings at Stage 8 are characterised by the increasing use of enclosures or pairs of lines, rather than single lines, to represent body parts such as arms and legs.



APPENDIX 2**ASSESSMENT ACTIVITY PROTOCOLS****TEDDY'S BEADS**

Four teddy bears were set out in a quiet area of the nursery, lined up from left to right. The first was Pudsey Bear, with an eye patch but no necklace; the second was Betty Bear, wearing a necklace with a repeated pattern of yellow and green beads; the third was Baby Bear with a yellow and green necklace with no patterning; and the fourth was Polar Bear, with a necklace of yellow and green beads in a symmetrical arrangement.

The adult followed the script below, leaving pauses for the child's practical and verbal responses after questions and instructions:

Come and say hello to the Bears. They've come to nursery to play with us today. This is Pudsey Bear; this is Betty Bear; this is Baby Bear and this is Polar Bear. They've been very busy threading and they've made some beautiful necklaces. Have a look. This is Betty's necklace; this is baby's necklace; and this is Polar's necklace. Aren't they nice? Which necklace do you like best? ...

Mmm, I like that one too. What do you like about that one?

(Expression of agreement if appropriate e.g. Yes, it is.)

Now let me tell you about Pudsey Bear. He's very sad because he's got a poorly eye and he couldn't make a necklace today. He would like a necklace just the same as Betty's necklace. Can you make one that's the same as Betty's? Thankyou. Let's take this off and have a look....

Thankyou very much. He likes that a lot. We'll put it down here just for a minute. Now, shall we put Betty Bear's back on? Let's tie it round. (Six beads are knocked off the necklace, as if by accident.) Oh dear, what's happened? Oh no, I've dropped some and made a mess. Let's put these beads back in the tray. (Beads are replaced in the tray.)

Wait a minute. I've and idea. You're good at threading. Can you mend this for Betty, please?

Oh, thankyou. That's lovely. Let's put this back on and Pudsey's necklace too. I think everyone's happy now. (The necklaces are put back on.)

Wait a minute. Somebody's sad. Baby Bear's sad because she doesn't like this necklace. She want's a necklace with a pattern on it. Can you make one with a pattern for baby bear?

Thankyou. That's beautiful Well all the bears are happy now. But there's one last thing you can do to help. They want to take a necklace home to their mum. Mummy Bear likes patterns with red, yellow and green beads. (The three colours of beads are held up as they are named.) Can you make a pattern with red, yellow and green? ...

Thankyou. That's lovely.

REQUEST FOR CLARIFICATION: BEADS AND MOSAIC TILES

The adult followed the script below in response to a child's request for clarification of the meaning of 'pattern' e.g. "What's a pattern?"

You need more than one bead/tile to make a pattern. You need a few. To make a pattern, you need to think carefully about which colours go next to each other.

REQUEST FOR CLARIFICATION: PEGS AND PEGBOARD

The adult followed the script below in response to a child's request for clarification of the meaning of 'pattern' e.g. "What's a pattern?"

You need more than one peg to make a pattern. You need a few. To make a pattern, you need to think carefully about where you put the pegs. If you like, you can choose one, two or more than two special colours for the pattern.

APPENDIX 3**WORKED STATISTICS****SIMPLE CHI-SQUARE****Teddy's Beads 1: proportional success when copying a simple 2 unit repeating pattern**

Null hypothesis: there is no relationship between age and children's skills in copying a simple 2 unit repeating pattern in the age group studied.

Observed frequencies

	Successful	Unsuccessful	Totals
3½ years	Cell A 3	Cell B 46	49
4½ years	Cell C 18	Cell D 31	49
Totals	21	77	98

Calculate expected frequencies

$$\text{Cell A: } \frac{49 \times 21}{98} = 10.5$$

$$\text{Cell B: } \frac{49 \times 77}{98} = 38.5$$

$$\text{Cell C: } \frac{49 \times 21}{98} = 10.5$$

$$\text{Cell D: } \frac{49 \times 77}{98} = 38.5$$

Calculate the difference between the observed and the expected frequencies using Yates' correction

$$\text{Cell A: } 10.5 - 3 - 0.5 = 7$$

$$\text{Cell B: } 46 - 38.5 - 0.5 = 7$$

$$\text{Cell C: } 18 - 10.5 - 0.5 = 7$$

$$\text{Cell D: } 38.5 - 31 - 0.5 = 7$$

Square each cell value and divide by the expected cell frequency

$$\text{Cell A: } \frac{(7)^2}{10.5} = 4.7$$

$$\text{Cell B: } \frac{(7)^2}{38.5} = 1.3$$

$$\text{Cell C: } \frac{(7)^2}{10.5} = 4.7$$

$$\text{Cell D: } \frac{(7)^2}{38.5} = 1.3$$

Add the 4 values to obtain χ^2

$$4.7 + 1.3 + 4.7 + 1.3 = 12$$

The obtained value of 12 exceeds the tabulated value of 10.83, which is significant at the 0.001 level (one-tailed test, one degree of freedom). The null hypothesis can be rejected.

THE WILCOXON TEST

Comparison of colour organisation levels for Mosaic Tiles 2 at Assessment 1 and Assessment 4

Null Hypothesis: there is no significant difference between the levels achieved by children at Assessments 1 and 4 for Mosaic Tiles 2.

Child	Assessment 1	Assessment 4
A	4	5
B	1	4
C	2	3
D	1	1
E	1	4
F	1	5
G	4	6
H	1	5
I	1	6
J	1	3
K	1	3
L	4	4

Child	Assessment 1	Assessment 4
M	5	3
N	1	3
O	1	4
P	5	5
Q	3	5
R	1	5
S	5	2
T	1	1
U	5	5
V	1	5
W	3	5
X	2	1

Pair the scores and calculate the differences

Child	
A	$5 - 4 = 1$
B	$4 - 1 = 3$
C	$3 - 2 = 1$
D	$1 - 1 = 0$
E	$4 - 1 = 3$
F	$5 - 1 = 4$
G	$6 - 4 = 2$
H	$5 - 1 = 4$
I	$6 - 1 = 5$
J	$3 - 1 = 2$
K	$3 - 1 = 2$
L	$4 - 1 = 3$

Child	
M	$3 - 5 = -5$
N	$3 - 1 = 2$
O	$4 - 1 = 2$
P	$5 - 5 = 5$
Q	$5 - 3 = 2$
R	$5 - 1 = 4$
S	$2 - 5 = -3$
T	$1 - 1 = 0$
U	$5 - 5 = 0$
V	$5 - 1 = 4$
W	$5 - 3 = 2$
X	$1 - 2 = -1$

Rank the differences according to size

Child	Score	Rank
A	1	2
B	3	12½
C	1	2
D	0	
E	3	12½
F	4	16½
G	2	7
H	4	16½
I	5	20
J	2	7
K	2	7
L	3	12½

Child	Score	Rank
M	-5	20
N	2	7
O	2	7
P	5	20
Q	2	7
R	4	16½
S	-3	12½
T	0	
U	0	
V	4	16½
W	2	7
X	1	2

Add the ranks for differences

Positive difference ranks: $3(2) + 7(7) + 3(12\frac{1}{2}) + 4(16\frac{1}{2}) + 2(20) = 6 + 49 + 37\frac{1}{2} + 66 + 40 = 198\frac{1}{2}$

Negative difference ranks: $20 + 12\frac{1}{2} = 32\frac{1}{2}$

$T = 32\frac{1}{2}$

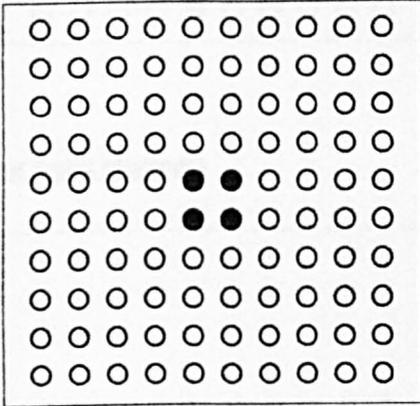
There are 24 pairs of scores and 3 values of 0. $N = 21$

Evaluation of Wilcoxon's T statistic

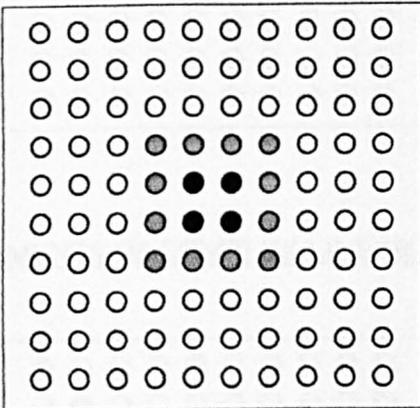
The obtained value of $32\frac{1}{2}$ is significant at the 0.005 level for a one-tailed hypothesis.

APPENDIX 4**2D SYMMETRICAL PATTERNS**

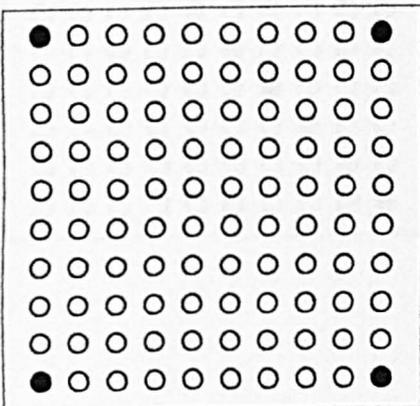
2D symmetrical patterns incorporate two or more of the following basic elements of pattern and/or forms of complex linear organisation.

BASIC ELEMENTS OF PATTERN**Non-linear basic elements***Marking the centre - sustained*

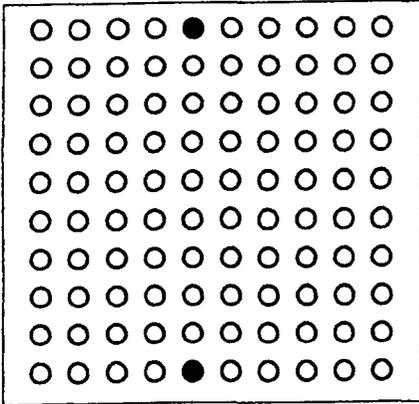
A square is marked by placing four pegs consecutively in a 2x2 arrangement.

*Enclosing the centre - sustained*

A centre is enclosed by placing twelve pegs around a marked centre.

*Marking the corners – sustained*

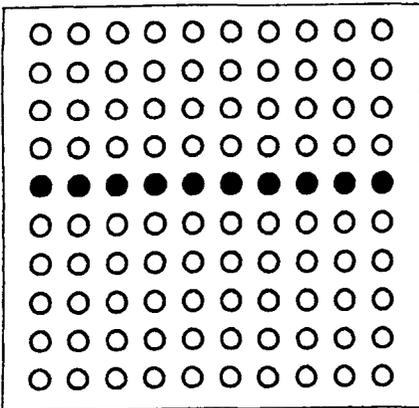
The corners are marked by placing four pegs consecutively in the four corners.



Marking two mid-points

Two mid-points are marked by placing two pegs consecutively on opposite midpoints of two sides of the pegboard.

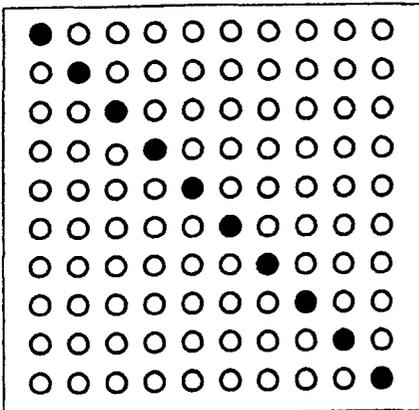
Linear basic elements



Marking a midpoint line

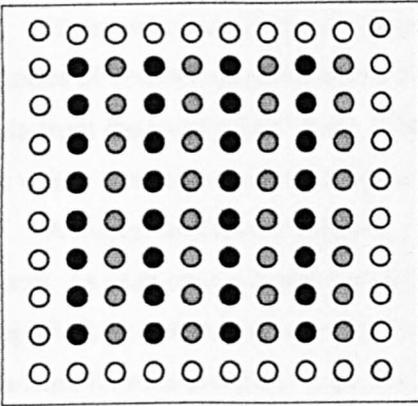
A mid-point horizontal line is marked by pegs using unidirectional, proximity placement/ symmetrical markings. Similarly, a midpoint vertical line can be marked.

ELEMENTS OF COMPLEX LINEAR ORGANISATION



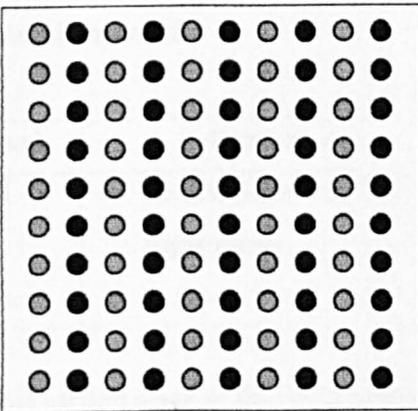
Marking a diagonal line

A sustained diagonal line is marked by unidirectional proximity placement.



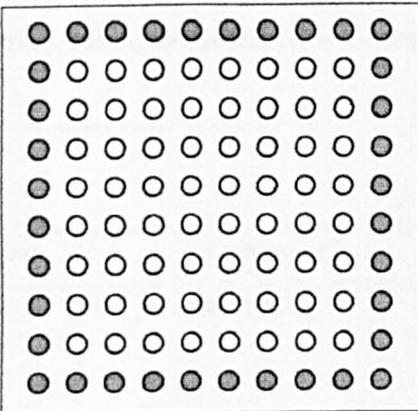
Marking 8 parallel horizontal/vertical lines

Eight repeated and sustained lines are marked with unidirectional proximity placement.



Marking 10 parallel horizontal/vertical lines

Ten repeated and sustained lines are marked with unidirectional proximity placement.



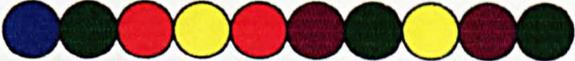
Marking 4 connected lines

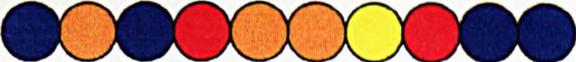
Four connected lines are marked with unidirectional proximity placement to make a rectangle.

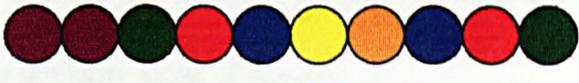
APPENDIX 5**COLOUR ORGANISATION: THE HYPOTHESISED DEVELOPMENTAL PATHWAY**

Exemplification of the developmental pathway for colour organisation draws on categories of colour organisation matched to level descriptions, as identified during the analysis of data from the longitudinal study. The one or two categories used for exemplification are those which were observed most frequently in the data for children at 4½ years.

A logical analysis of repeated pattern-making as a task supports the hypothesised pathway. As each level of colour organisation in the hypothesised developmental pathway is exemplified, its links to the previous level are highlighted. From level 3 onwards, the behaviours focused on colour organisation at each level of the pathway involve the co-ordination, refinement, extension or sustaining of behaviours focused on colour organisation from the previous level. Additionally, within level developments marking progress towards the next level are noted.

Level	Descriptor	Category
1	<ul style="list-style-type: none"> no evidence of colour organisation 	random selection 
<p>At this earliest stage of the developmental sequence, children initially focus on aspects of the task other than colour e.g. the social context; the physical act of threading; the length of the necklace. Children working at this level may begin to focus attention on the colour of play materials, asking questions about colours.</p>		

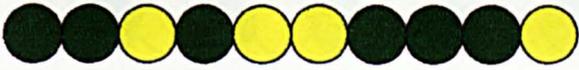
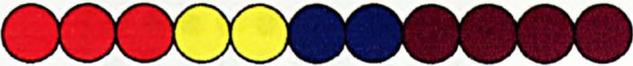
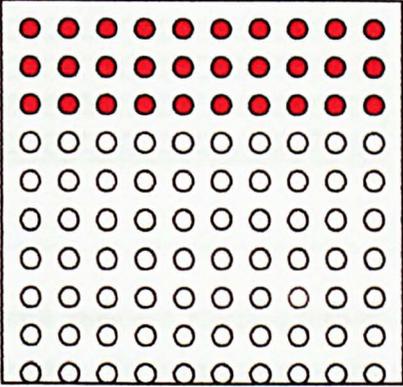
Level	Descriptor	Category
2	<ul style="list-style-type: none"> colour naming 	a unit  <hr style="width: 10%; margin-left: 0;"/> The child says, "Blue one."
<p>At Level 2, children focus attention on the colour of play materials and express this verbally e.g. as materials are selected; as materials are threaded or placed; as completed work is discussed. Initially, colour naming may be inaccurate. For some children, colour naming represents a refinement of the focus on colour, expressed through questioning at Level 1.</p>		

Level	Descriptor	Category
3	<ul style="list-style-type: none"> colour grouping based on relationships of similarity or difference 	<p>a similarity group</p>  <p>The child says, "Lots of greens."</p> <hr/> <p>a difference group</p>  <p>The child says, "Yellow one... orange.... Blue."</p>

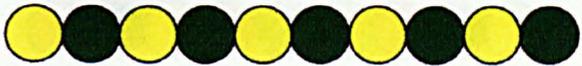
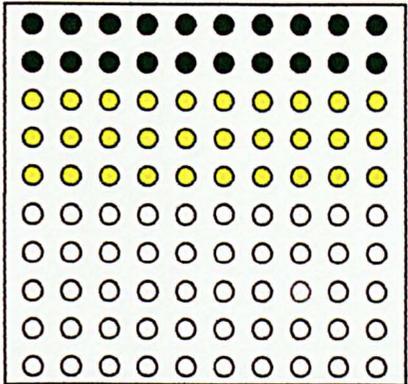
At Level 3, children co-ordinate, within a single play episode, the attention previously focused on the colours of two or more individual components of play materials across play episodes. Attention focused on the different colours of components is verbalised through the use of colour names. It may be demonstrated through sorting and sequencing behaviours. Attention focused on the similar colours of components may be verbalised. Alternatively, it may be demonstrated through sorting and sequencing behaviours.

Initially, focus play materials may be placed nonconsecutively. At the upper stage of this level, focus materials are placed consecutively as a discrete similarity or difference group.

Children working at the upper stage of this level will focus attention on both the similarities and the differences between the colours of components of play materials, either within a single play episode or during different play episodes.

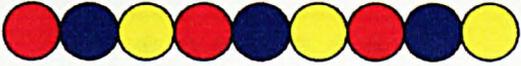
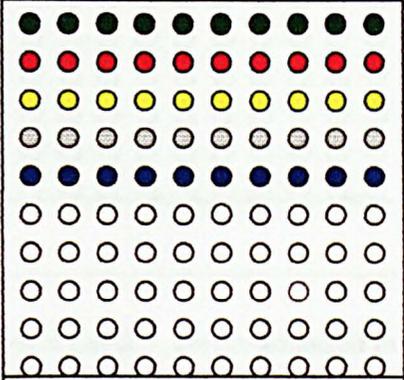
Level	Descriptor	Category
4	<ul style="list-style-type: none"> colour sequencing based on relationships of similarity and difference 	<p>alternated similarity groups and units</p>  <hr/> <p>chained similarity groups</p> 
	<ul style="list-style-type: none"> 2D colour grouping based on relationships of similarity 	<p>a similarity group of line unit</p> 

At Level 3, children focus attention in a discrete way on the similarities and differences between colours of components of play materials. At Level 4, these behaviours are co-ordinated within a single sequence. At Level 4, similarity groups or units in two or more colours are alternated, while similarity groups are chained. Initially, no attention is focused on numerosity. Additionally, difference groups may be chained but without a consistent focus on order within the sequence. During level 4, children begin to focus on numerosity in the context of firstly chaining and secondly alternating units and groups. A consistent focus on numerosity is developed in the context of chaining. At Level 3, children sustain attention, in linear work, on the similarity of colours of components of play materials. At Level 4, this attention on similarity groups is further sustained in the context of 2D work with pegs.

Level	Descriptor	Category
5	<ul style="list-style-type: none"> linear repeated pattern-making 	a repeated difference group 
	<ul style="list-style-type: none"> 2D colour sequencing based on relationships of similarity and difference 	chained similarity groups of line units 

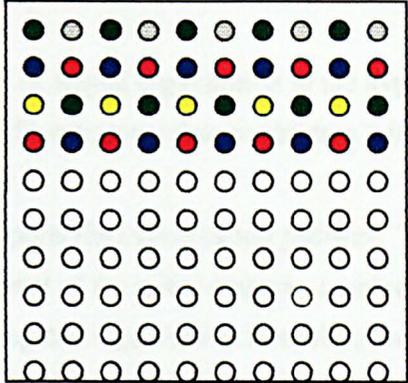
At level 5, children continue to coordinate, within a single sequence, attention focused on both the similarities and the differences of colours of components of play materials. At this stage, however, the focus on colour is coordinated with a consistent focus on numerosity and ordering. At this level, the consistent focus on numerosity and ordering is established in the context of 2 unit repeated sequences only.

At level 4, children first coordinate, within a single sequence, attention focused on both the similarities and the differences of colours. At Level 5, this attention on the similarity and differences of colours is further sustained in the context of 2D work with pegs.

Level	Descriptor	Category
6	<ul style="list-style-type: none"> complex linear repeated pattern-making (3+ units) 	<p>a repeated difference group – 3 units</p> 
	<ul style="list-style-type: none"> complex 2D colour sequencing based on relationships of similarity and difference 	<p>a difference series of line units</p>  <p>One line unit is made from each available colour category</p>

At Level 6, behaviours of Level 5 are extended. The colour organisation achieved in the context of 2 unit repeated sequences is extended to sequences based on relationships of similarity and difference incorporating three or more colours.

Additionally at Level 6, a complex Level 4 example of colour sequencing, based on relationships of similarity and difference, is sustained in the in the context of 2D work with pegs.

Level	Descriptor	Category
7	<ul style="list-style-type: none"> 2D repeated pattern-making 	<p>chained alternating line units</p> 

At Levels 7, the 2 unit repeated sequences, established at Level 5, are co-ordinated in the context of 2D work with pegs. Children extend their focus on relationships of similarity and difference within a linear sequence to focus on relationships of similarity and difference between linear sequences. They begin to extend the earlier focus, on ordering components by colour within a linear sequence, to a focus on the ordering of a sequence of linear sequences.

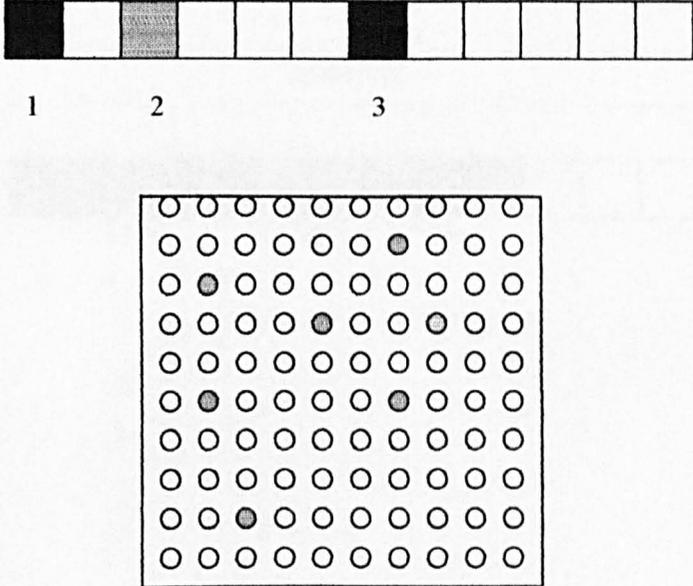
APPENDIX 6**BASIC LINEAR ORGANISATION: THE HYPOTHESISED DEVELOPMENTAL PATHWAY**

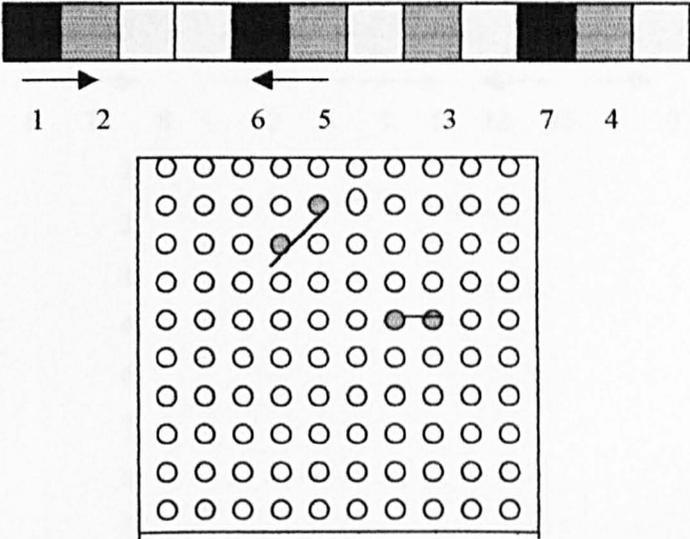
Two descriptors are presented for each level of spatial organisation in the hypothesised developmental pathway to basic linear organisation. Descriptors relate to children's linear work in Mosaic Tiles and in Pegs and Pegboard.

A logical analysis of linear organisation supports the hypothesised pathway. The behaviours focused on spatial organisation at each level of the initial pathway involve the connecting and extending of behaviours focused on spatial organisation from the previous level. As each level of spatial organisation in the hypothesised developmental pathway is exemplified, its links to the previous level are highlighted.

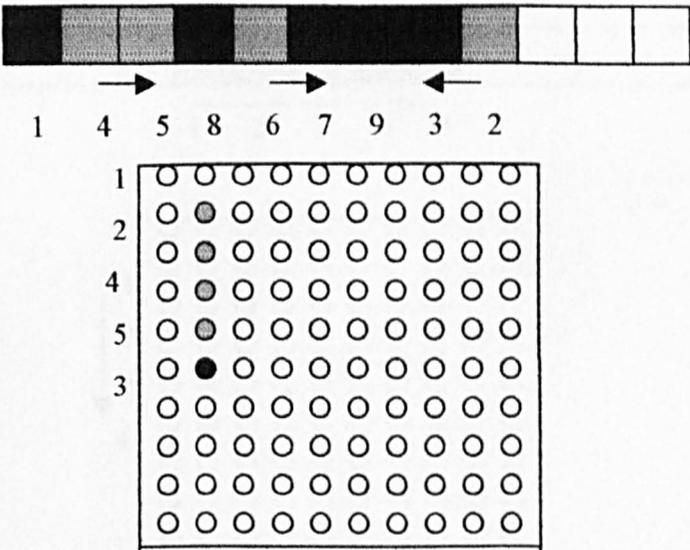
Recording spatial organisation:

- Black and grey are used to represent play materials. They do not represent particular colours.
- The numerals represent the placement order of play materials.

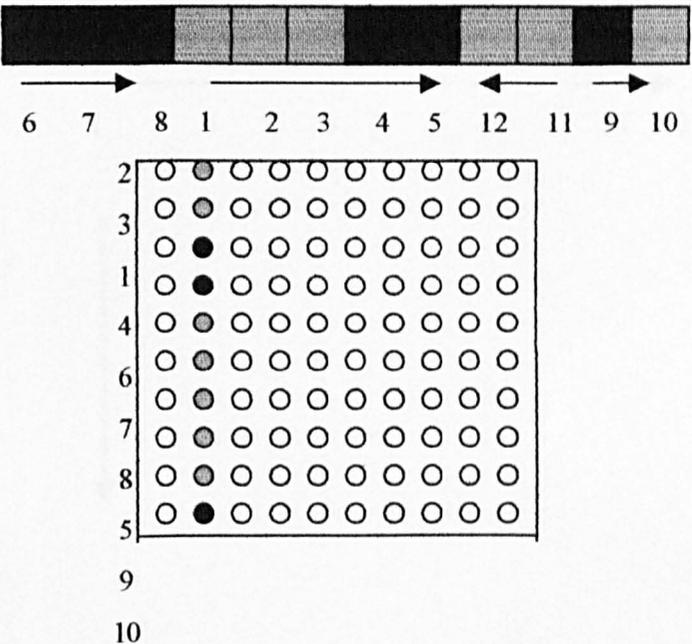
Level	Descriptor	Examples
1	<ul style="list-style-type: none"> • random placement 	
<p>At this earliest stage of the developmental sequence, children initially focus on aspects of the task other than spatial relations e.g. the social context; the physical act of placing components; imaginative content.</p>		

Level	Descriptor	Examples
2	<ul style="list-style-type: none"> proximity placement 	

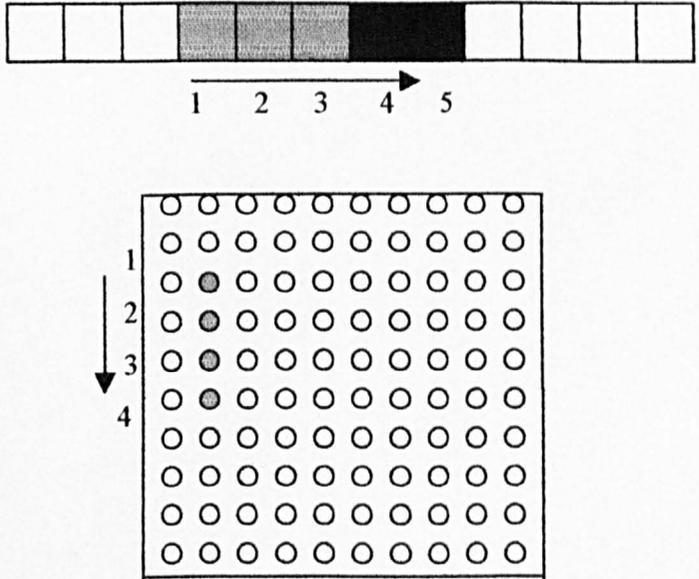
At Level 2, children focus attention on the spatial relation of proximity between two components of play materials. Two components are placed next to each other.

Level	Descriptor	Examples
3	<ul style="list-style-type: none"> multi-directional proximity placement - partial line 	

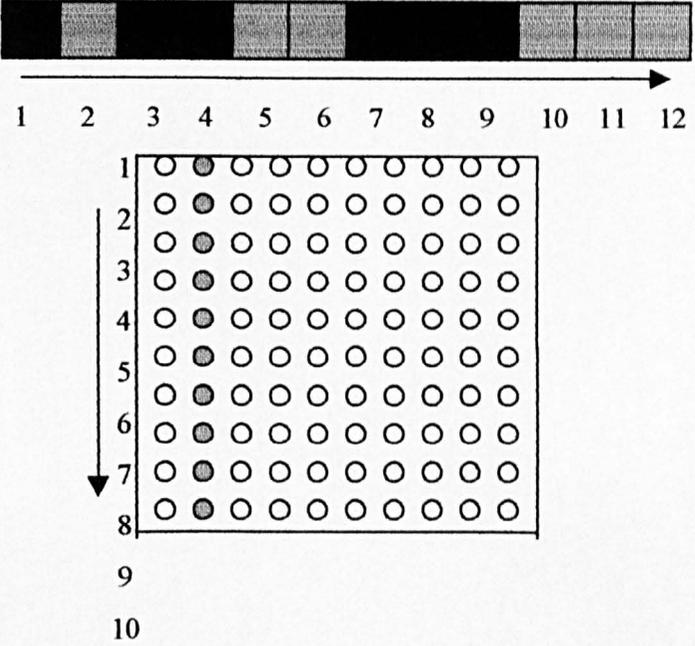
At Level 3, children continue to make proximity placements for one or more pairs of components. Additional play materials are used to connect or extend the proximity placements, making a partial line

Level	Descriptor	Examples
4	<ul style="list-style-type: none"> multi-directional proximity placement - sustained line 	 <p>The examples for Level 4 consist of two parts. The first part is a horizontal bar divided into segments labeled 6, 7, 8, 1, 2, 3, 4, 5, 12, 11, 9, and 10. Below the bar, arrows indicate movement: from 6 to 7, 7 to 8, 8 to 1, 1 to 2, 2 to 3, 3 to 4, 4 to 5, 5 to 12, 12 to 11, 11 to 9, and 9 to 10. The second part is a dot grid with 10 columns and 10 rows. The columns are labeled 2, 3, 1, 4, 6, 7, 8, 5, 9, and 10. A path of filled circles starts at the intersection of column 2 and row 2, moves down to row 3, then right to column 1, then right to column 4, then right to column 6, then right to column 7, then right to column 8, then right to column 5, then right to column 9, and finally right to column 10.</p>

At Level 4, children continue to make proximity placements. Additional play materials are used to connect or extend the proximity placements, making a complete line.

Level	Descriptor	Examples
5	<ul style="list-style-type: none"> uni-directional proximity placement - partial line 	 <p>The examples for Level 5 consist of two parts. The first part is a horizontal bar divided into segments labeled 1, 2, 3, 4, and 5. Below the bar, an arrow points from segment 1 to segment 5. The second part is a dot grid with 10 columns and 10 rows. The rows are labeled 1, 2, 3, and 4. A vertical path of filled circles starts at the intersection of the first column and row 1, moves down to row 2, then down to row 3, and finally down to row 4.</p>

At Level 5, children continue to make proximity placements. These are extended in a single direction, making a partial line.

Level	Descriptor	Examples
6	<ul style="list-style-type: none"> uni-directional proximity placement – sustained line 	 <p>The first example shows a horizontal line of 12 segments. The segments alternate in a pattern: black, grey, black, grey, black, grey, black, grey, black, grey, black, grey. An arrow points to the right below the line, starting from the first segment.</p> <p>The second example shows an 8x10 grid of circles. The first column of circles is shaded grey. A vertical arrow points downwards on the left side of the grid, starting from the top row.</p>
<p>At Level 6, children continue to make proximity placements for components. Proximity placements are further extended in a single direction, making a complete line.</p>		