Quantity-Comparative Expression in Young Children: An Analysis of Responsive and Productive Language

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QUANTITY-COMPARATIVE EXPRESSION IN YOUNG CHILDREN: AN ANALYSIS OF RESPONSIVE AND PRODUCTIVE LANGUAGE

by

Sandra-Rae Howe

A Dissertation Submitted to the Faculty of The Graduate College in partial fulfillment of the requirements for the Degree of Doctor of Education Department of Educational Leadership

Western Michigan University Kalamazoo, Michigan December, 1982
QUANTITY-COMPARATIVE EXPRESSION
IN YOUNG CHILDREN: AN ANALYSIS OF RESPONSIVE
AND PRODUCTIVE LANGUAGE

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When used in mathematics instruction, quantity-comparative language has specific meaning which may be confusing or unfamiliar to young children. Because of the importance of language to the development and measurement of understanding of math concepts, the purpose of this study was to examine the abilities of young children to produce and to understand quantity-comparative descriptions.

Ninety-seven five-year-olds, selected by a stratified random sampling of children in early childhood facilities, were interviewed individually. Each interview consisted of an introductory activity, a productive language assessment (to elicit, in the subject's own language, descriptions of quantity comparisons), and a responsive language assessment (to examine the subject's ability to respond correctly to conventional quantity-comparative terms).

The results indicated that many children do have the ability to describe quantity comparisons and to respond correctly to the conventional terms that were assessed. However, the children appeared to have varying levels of facility in producing, and responding to, quantity-comparative language. The degree of math-specificity of the term and the direction of the comparison (larger, smaller, or equal amounts) appeared to be influencing factors. It was found that many children were unable to respond correctly to certain conventional terms even though they were able to describe the same comparisons in their own language.
Analysis of the assessment scores indicated a positive correlation between the productive language and the responsive language abilities of the children. No significant difference could be shown between girls and boys in either their productive or their responsive language abilities, nor could a difference be shown in the productive language abilities of Black and Caucasian children. However, Caucasian children scored significantly higher in the responsive language assessment. It was also found that children of more highly-educated mothers had significantly higher scores in both productive and responsive language.

An examination of the quantity-comparative vocabulary of typical kindergarten mathematics programs revealed a wide variation in the vocabulary and the level at which terms were introduced. A comparison of the textbook vocabularies with the actual language abilities of the children in this study suggested the need for greater emphasis on the language implications of math instruction.
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ACKNOWLEDGEMENTS

Over the past ten years I have become increasingly intrigued by the processes through which young children learn mathematics. As an elementary teacher, I found myself questioning curricula and instructional procedures in an attempt to help children avoid early failures in learning mathematics. Since that time, many people have influenced, encouraged, and assisted me in my various endeavors which eventually led to this investigation.

I would like to acknowledge my friend and former colleague, Marlene Schroeder, whose skill in teaching math to young children initially sparked my interest in the subject. Also, I am especially grateful to Dr. Mary Cain for her friendship and her unfailing belief in me. She has been a guiding influence since we first met.

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Sandra-Rae Howe
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CHAPTER I

INTRODUCTION TO THE PROBLEM

It is often overlooked that language is fundamental to the development of mathematics skills. Many words that adults take for granted, such as those used to compare quantities (more, bigger, less, same), can pose a problem for the child encountering beginning mathematical concepts. Some of these comparative or quantity phrases are within the realm of the child's natural language and are easily used and understood. Often, however, the words a child uses to compare quantities are not the same as the terms used in the instructional language of mathematics. In fact, the young child may have no comprehension of some of the words being used in beginning math instruction, especially those which have specific mathematical uses such as fewer, greater, equal, and less. Additionally, the child's mastery of beginning math skills is generally assessed on the basis of his or her ability to describe and to explain quantity relationships. Thus, language becomes a critical vehicle for demonstrating understanding of math concepts.

While it may seem obvious that language plays at least some role in the development of beginning math concepts, research in this area is complicated by the fact that three formal disciplines are involved: cognitive development research, linguistics research, and mathematics education research. Each of the disciplines has tended to focus its research attention on specific areas of study with very limited communication among the disciplines.

The relationship between language and cognitive processes has been studied at length. Specifically, researchers (Beilin, 1968; Calhoun, 1971;
LaPointe and O'Donnell, 1974; Rothenberg, 1969; L. Siegel & Goldstein, 1969; L. Siegel, 1978) have established that young children have great difficulty understanding relational terminology such as more, longer, less, and same. Studies by Brush (1978), Cohen (1967), and Grieve and Dow (1981) have illustrated that young children frequently misinterpret and confuse comparative words. Much of this confusion arises from the domination of the young child's judgments by his or her perceptions. For example, four large objects are often judged by the child to be more than four or even five smaller objects. To the young child, bigger is more. This example also illustrates a second area of confusion for the young child, namely, the ambiguity of certain comparative terms. Four large objects do cover more space than five smaller objects, but five smaller objects are more in the numerical sense.

While there is considerable research on the interaction between cognitive capacities and relational terminology, most studies have focused on the child's response to specific relational terminology. Few have looked at the children to find out what, if any, language is used spontaneously by the young child to describe quantity relationships. Martin (1951) explored young children's abilities to respond spontaneously to quantitative stimuli and related this to a measure of the child's number ability. His findings showed that children do use quantitative vocabulary spontaneously in response to quantity situations and that this quantity vocabulary becomes more versatile and is used more extensively as the child gets older. More recently, L. Siegel (1977, 1978, 1982) has studied the relationship between children's linguistic skills and their quantitative concepts. Her findings indicated that language and thought function independently in the young child and, as the child develops, concepts and language tend to be more related. In another study, L. Siegel (1982)
concluded that appropriate quantity language does not appear to be used spontaneously.

Other assessments of production of quantitative language have been modifications of the Piagetian conservation of number studies, using nonverbal assessment techniques. It should be noted that such studies are not literally nonverbal (i.e. without words) but attempt in some manner to overcome the often-criticized language dependence of Piaget's approach. Griffiths, Shantz, and Sigel (1967) asked the child to describe two sets of lollipops. Ehri (1976) asked how one "bunch" of objects differed from another "bunch". Calhoun (1971) and Mehler and Bever (1967) used motivated choice approaches by asking the child to "pick the row of candies you would like to eat." Other studies (Estes, 1976, Gelman, 1972a; Kendler, 1964; Miller 1980) motivated choice differently by focusing the child's attention on a specific size dimension in a training session. During the assessment, the child indicated his or her recognition of the comparison by making a choice between stimulus cards (for example, naming the "winner", or earning a token, or finding the happy face) and explaining why the choice was made.

The findings of such studies are ambiguous, as Miller (1976) indicated in a review of nonverbal assessments of Piagetian concepts. In many of the studies, performance was approximately the same as on standard Piagetian tasks, while numerous other studies provide evidence that an understanding of conservation may develop earlier than Piagetian theory suggests. Nonetheless, the findings from these studies provide information about the child's language. Specifically, these studies have indicated: that children may be able to solve a task but not be able to verbalize their reasons for their actions; that children may understand the meaning of relational terms but may not spontaneously use
those words; and that children may be able to solve quantitative tasks when the methods of assessment do not require verbal encoding.

In a review of research on mathematics in early childhood, Suydam and Weaver (1975) indicated surprise that so little actual research has been done on early childhood mathematics education. L. Siegel (1971) lamented the fact that data from studies of isolated aspects of the development of quantitative concepts in young children have not been integrated. She felt that it is because of this fragmentation of research that little is actually known about the sequence of appearance of these concepts and the manner in which they develop in young children.

Cognitive development research has been the basis of many mathematics-related studies in an attempt to relate the implications of child development to mathematics education. A large number of studies has been inspired by Piagetian research but, according to Ginsburg and Russell (1981), the relationship between success or failure at conservation tasks and the cognitive skills involved in school mathematics is not yet clear.

Gelman (1972a, 1972b; Gelman & Gallistel, 1978) has investigated the development of the processes young children use to solve quantitative problems. Her findings indicated that very young children can solve quantitative problems if the amounts are sufficiently small (three or less). However, Zimiles (1963) characterized the preschool child's concept of quantity as somewhat amorphous and ambiguous. Ginsberg (1977) described the child's early mathematics as intuitive, strongly influenced by perception, and often nonverbal. Dienes (1973) asserted that children's experiences are the basis of their developing math concepts. Further, he claimed that the child's knowledge of a concept at an intuitive level must precede any logical analysis or
explanation and that learning a concept is enhanced when children are exposed to it through a variety of experiences.

Several background attributes have been suggested to influence both cognitive and language development in young children. Traditionally, young girls are perceived to outperform young boys on academic tasks. Girls are also generally characterized as having superior verbal skills at the preschool level. However, mathematics has long been viewed as an area in which males outperform females. A discussion of research supporting and refuting these perceptions is not considered relevant to this study. It will be sufficient to say that traditional sex-role perceptions are not easily overcome despite strong research findings which do not support these tenets. In their research on sex differences and quantitative language of young children, Calhoun (1971) and Moore and Harris (1978) found no significant differences between males and females. Martin (1951) found that, although girls were generally more loquacious than boys, boys used more quantity-related words.

In a recent study of social class and racial influences on early mathematical thinking, Ginsburg and Russell (1981) found few significant differences associated with either factor. Martin (1951) found that superior quantitative vocabulary was typical of children from upper occupational groups. Austin and Howson (1979) discussed the findings of several researchers and concluded that the language of mathematics instruction favors "middle-class" students.

In sum, many researchers have referred to the importance of language to developing math skills in young children and to the difficulty young children experience with specific relational terminology. Despite this, there has been little attempt to assess children's productive language in quantity-comparative situations. Nor has any clear relationship been established between language acquisition and the development of math concepts.
Purpose of the Study

The purpose of this investigation was to examine young children's production and understanding of quantity-comparative language, to provide a description of the language abilities of children who are about to enter kindergarten. The study was undertaken not only to help clarify some of the findings of related research, but also to lead to math curriculum recommendations at the kindergarten level. Within the context of that purpose, there were five specific objectives:

1. To measure and describe the language produced by young children in making quantity comparisons (productive language);

2. To measure young children's understanding of conventional quantity-comparative terms through an examination of their ability to respond appropriately to the verbal use of the terms (responsive language);

3. To determine the association between levels of productive and responsive language;

4. To determine whether differences existed in levels of productive and responsive language among children grouped according to sex, race, and mother's education (since the mother is traditionally the primary caregiver in the early years and, thus, the major influence on the child's developing language, this study considered the mother's education rather than social class);

5. To compare the children's understanding and production of quantity-comparative terms with the terms used in typical kindergarten math textbook series.

Rationale

According to Gelman (1978), the cognitive shortcomings of the preschooler are many and well-documented. Unfortunately, however, not nearly as much is known about what a young child can do cognitively, mathematically, and linguistically. While teachers of young children can often identify the math-specific words their students have difficulty with, a compilation of the...
terms young children actually tend to use in making quantity comparisons is not available in curricular or research literature.

Fell and Newnham (1978) have suggested that it is not possible to know in detail what the teacher of young children ought to do in the teaching of mathematics. Although a relationship seems to exist between mathematical concepts and linguistic knowledge, the number of studies addressing this issue has been quite small, and the findings have not been translated into a workable curriculum. The compilation of a list of quantity-comparative descriptions produced spontaneously by the children in this study will provide descriptive information which may serve as a basis for further study in this field. While no conclusions can be drawn from the list itself, curricular considerations for young children's math instruction may be indicated. From a description of the comparative language skills of a particular group of entering kindergarten children, existing kindergarten programs may be examined to determine whether they provide opportunities for learning math which are commensurate with the skills of the children in this study.

A similar rationale exists for measurement of children's ability to respond to conventional quantity-comparative terms. If the children of this study consistently have difficulty responding to certain terms used, we may infer a need to assess mathematics curricula to see where these words are first used in the sequence of instruction. If the terms which have caused difficulty in this study are part of the kindergarten or first grade math curriculum, attention ought to be given to the students' understanding of these terms and to language development prior to the use of the terms in mathematics instruction.
Linguists (Cocking & McHale, 1981; Griffiths et al., 1967) have reported that young children may understand the meaning of relational terms without using them spontaneously. According to the linguists' findings, one would expect the analysis of association between responsive and productive language to show generally higher responsive language scores than productive language scores. However, since the productive language assessment used in this study provided an opportunity for children to describe quantity comparisons in their natural language, it may be shown that children are able to produce informal, natural-language quantity comparisons prior to being able to respond appropriately to conventional quantity-comparative language.

Finally, it has been indicated (Dale, 1976) that widely held generalizations about language differences based on sex, race, and social class are not supported as well as would be supposed. By analyzing the language abilities of the children for apparent influence of background or demographic factors, this study will examine whether such differences can actually be shown in the children's productive or responsive language.
CHAPTER II

CONTEXT OF THE PROBLEM

Introduction

A review of the literature related to young children's use and comprehension of relational language requires a review of several different yet overlapping areas. The first area to be considered must be the relationship of language and thought, for cognitive development cannot accurately be measured without language, and vice versa. Following the general discussion of cognitive development and language, the review narrows to the specific area of concern for this study, the young child's language and conception of quantity comparisons. As we have seen, a study of this type is complicated by the fact that it involves disciplines which generally have not collaborated in their study of young children. Therefore, the discussion of the young child's language and conception of quantity comparisons is divided into three sections: conservation of number, which reflects cognitive development studies; a mathematics perspective, which describes relevant studies in mathematics education; and a language perspective, which deals with the findings of linguistics research. The third area of review discusses studies which have looked specifically at language influences on mathematics development. Finally, demographic considerations related to the study are reviewed.

Cognitive Development, Language, and Thought

The relationship between language and thought has been studied at length. Theories vary widely and, according to Moore and Harris (1978),
considerable disagreement exists about the mental operations or competence that ought to be attributed to children on the basis of what they say.

The literature reveals four different views on the relationship between language and thought. One theory is that no relationship exists between the development of thought and the acquisition of language skills. Another opinion is that the child's developing language skills promote the development of cognitive skills. A third belief is that the child's developing cognitive skills facilitate the development of language skills. And, as might be expected, a final view is that there is a complex interrelationship between the development of thought and language in young children.

Behavioral psychologists (Skinner, 1957; Watson, 1924) viewed language and thought as the same. Language was considered evidence of the existence of cognitive ability. However, many have been critical of the behaviorists' theory which, according to Oleron (1977), ignored the relationship of language to children's performance.

Chomsky (1957, 1968) also strongly opposed the behaviorist position, and claimed instead that the capacity to learn language was governed by innate rules of grammar. This theory, referred to as nativism, proposed that the key forces of language development are the inborn capacities of the child.

Vygotsky (1962) also criticized theories which equated thought with speech. He has claimed that thought and speech are independent very early in life and that at some point near the end of the child's second year, when thoughts begin to be spoken, the two combine. At this stage, according to Vygotsky, language and thought become interdependent.

Piaget (1967, 1972) asserted that cognitive operations emerge and develop independently of language. He saw logical development as providing
the foundation for language. For Piaget, language reflected, rather than determined, cognitive development.

Bruner (1964) claimed that language represents experience. He felt that children employ a form of internalized speech to assist thought processes in solving cognitive problems. According to Bruner, the structure of language forms a structure for the development of logical thought. In contrasting the views of Piaget and Bruner on the relationship of language and thought, Guthrie (1981) stated: "Piaget uses changes in a child's way of thinking to explain the development of language, while Bruner uses changes in a child's use of language to explain the development of thought." (p. 6)

On the basis of studies with deaf adults and children, Furth (1966) concluded that intellectual functioning cannot depend upon language. Furth claimed that, although the profoundly deaf do show certain limitations, the development and structure of their intelligence are remarkably unaffected by the absence of verbal language.

According to Moore and Harris (1978), few empirical studies have directly examined language development within the context of cognitive development. Their review of the few relevant experiments described the findings as claiming either that cognitive development determines language development, or that language development does not determine cognitive development. They pointed out that the possibility of interdependence has largely been ignored. In their own study, Moore and Harris did not support the Piagetian theory that language skills are a reflection of cognitive operations.

Current research appears most concerned with exploring the interrelationship between language and thought. Dimitrovsky and Almy (1972) suggested that this intertwining of the two may vary with age, with the
individual, and even with the subject matter. Guthrie (1981) interpreted her findings as providing a strong indication of a symbiotic relationship between cognition and language.

According to Ausubel, Sullivan, and Ives (1980), it is becoming increasingly apparent that language and thought are indeed interrelated. However, the nature of the interaction between the two is still unresolved. Does the development of language skills precede and facilitate the development of cognitive skills, or is it the other way around? Or, are the dynamics of the development so complex that it may be impossible to determine the exact nature of the relationship? Or, is it possible that cognitive development facilitates language development in some children while the reverse is true for others?

The Young Child's Language and Conception of Quantities and Comparisons

Conflicting theories of the relationship between language and thought have raised concerns about the assessment of young children's abilities. Arguments have been made that, if cognitive capacities exist independently of, or prior to, the language to describe them, then measures which are dependent upon language do not, in fact, provide a true indication of children's abilities. According to L. Siegel (1978), if language is necessary to the measurement of cognitive abilities, the absence of that cognitive skill "cannot logically be inferred in a child of preschool age range whose language production and comprehension is immature for the task" (p. 47). This view has led to criticism of traditional Piagetian assessment techniques and to a search for appropriate nonverbal alternatives.
The following section will review research findings in three areas: first, the assessment of cognitive skills as they relate to children's understanding of quantity — specifically, the ability to conserve number; second, theories of the development of mathematical concepts in young children; and finally, studies of children's language skills which relate specifically to quantities and comparisons.

Conservation of Number

Opinions differ about the extent to which the ability to conserve number is related to the understanding of beginning number concepts. According to Piaget (1965), conservation of quantity is necessary to the understanding of number. Some investigators (Copeland, 1974; Dodwell, 1961; Rothenberg, 1969) suggested that tests of number conservation may be a meaningful measure of arithmetic readiness. Yet Ginsburg and Russell (1981) felt that the relationship between success or failure at conservation tasks and the cognitive skills involved in school mathematics was not yet clear. In their study of children's early mathematical thinking they found that, although many of the children failed to conserve number, this did not prevent them from performing many other tasks of mathematical thought adequately. Pennington, Wallach, and Wallach (1980), also noted that the positive correlations found by many researchers were rather weak; they felt that some degree of correlation should be expected simply on the basis of the types of concepts being measured.

Tasks of conservation of number assess the child's ability to treat a number as invariant. Gelman (1972a) described a typical test of number conservation: the child first is shown two identical sets of equal number (e.g., two rows of six chips placed in one-to-one correspondence) and then is asked if
both sets contain the same number. Children initially judge the sets as equal. Next, while the child watches, one row is spatially transformed, either lengthened or shortened (the number of objects is not changed). The child is again asked if both sets contain the same number and if not, which has more. Finally, the child is asked to explain his judgment. Children younger than six or seven usually rely on the perceptual cue of length and describe the longer row as having more chips. According to Piaget, this overreliance on perceptual cues prevents the preoperational child from comprehending the invariance of quantity.

Many researchers have suggested that failure on the number conservation task may be due to the language-dependent format of the task. According to Harasym, Boersma, and Maguire (1971), in order to respond correctly to a conservation task the child not only must perceive the presence or absence of equivalence, but also must understand the question posed and answer it verbally. Thus, failure on conservation tasks may be due to a child's linguistic incompetence rather than to cognitive abilities. They suggested that only those children who understand the meaning of relational terms can be successful on Piagetian assessments of conservation. In their view, such assessments do not provide a true measure of children's cognitive capacities.

Concern that the young child may possess abilities that are not tapped by standard Piagetian tasks has led investigators to devise alternative methods of assessment. Many of these techniques have been modifications of the Piagetian task using a nonverbal approach. In his review of these assessments, Miller (1976) stated that few of the methods are truly nonverbal but that all are intended to be less verbal than the standard Piagetian procedures. Additionally, Miller cautioned that while nonverbal measures yield interesting
data about young children's abilities, they often fail to capture the Piagetian concept that they are supposedly measuring. For example, in nonverbal measures of conservation of number, it is questionable whether methods which use two sets of unequal amounts assess the same skills as the Piagetian method which employs two equivalent sets.

Modifications of the standard Piagetian tasks have produced conflicting findings. Many studies using modified techniques (Braine, 1959; Calhoun, 1971; Gelman, 1972a, 1972b; Gelman & Gallistel, 1978; Mehler & Bever, 1967; Miller, 1980) reported that children generally do better, and at a younger age, than they do on a standard Piagetian assessment. However, several issues have been raised which complicate the interpretation of these studies. As Miller (1976) pointed out, performance on nonverbal assessments may be superior to standard measures, but for reasons unrelated to conservation. Some studies required judgments only, while the Piagetian criterion required judgment as well as adequate explanation for the judgment made. Studies in which children are not required to justify or to explain their response tend to result in more children being identified as able to conserve, and at a younger age. LaPointe and O'Donnell (1974) found that few preschool children who could give conservation responses could also produce correct explanations. Similarly, Dimitrovsky and Almy (1972) stated that younger children who respond correctly to conservation questions are significantly less likely to give appropriate explanations for their responses than are older children.

On one hand it may be argued that children's inadequate verbal skills may be preventing them from demonstrating their true conservation abilities on assessments which require explanations. On the other, it may be claimed that without an appropriate explanation for the choice it is impossible to know whether the child actually possesses the cognitive structures being assessed.
Tests of motivated choice (those in which a child is asked to indicate, for example, the row of candies he or she would like to eat) by necessity must use unequal sets. Piagetian assessment involves equal sets upon which a perceptual transformation is performed. Since it has been suggested (LaPointe & O'Donnell, 1974; Piaget, 1968; Rothenberg, 1969) that performance is superior on inequality tasks, this departure from standard procedure may in itself explain the differing results. In addition, Miller (1976) claimed that there is a much greater chance of false positive responses in motivated choice tests; children may choose the correct set at random or for reasons unrelated to conservation (such as preference or politeness). Motivated choice assessment methods have proved successful in eliciting responses from young children, but unfortunately there is no way to use this approach with equal sets.

Tests of instrumental choice use a nonverbal selection of one of the stimuli as judgment of understanding of same or different. During a preassessment training session the child is rewarded for choosing one of the two sets (for example, the larger). The child's ability to select the larger set during the actual assessment is considered evidence of conservation. Using this approach, Braine (1959) concluded that children can conserve considerably earlier than is indicated by standard assessment techniques. McLaughlin (1981) also employed this type of approach but her findings are more consistent with Piagetian theory.

L. Siegel (1972) used an approach in which the subject was required to recognize two sets that were identical in numerical size but which had different spatial arrangements. The results showed substantial performance superiority of four-year-olds, compared to the standard Piagetian assessment. She also noted that this matching-of-sets approach was considerably easier than the Piagetian assessment.
LaPointe and O'Donnell (1974) found that children responded quite differently when asked only one question (involving same) rather than the standard questions which involve same and more. They concluded that the child's ability to judge number progresses through a series of overlapping steps including: understanding of the comparison questions; judgments of numerical correspondence; and finally, judgments based on internalized rules that the child can articulate. Rothenberg (1969) saw two distinct substages of nonconservation. In the first, the child lacks understanding of the conservation questions. In the second substage, the child understands the language of conservation but is not yet able to conserve.

Another form of modified conservation assessment involves the element of surprise. In this type of assessment children are not required to make a choice, only to express surprise. According to Miller (1976), surprise occurs when expectance is violated; expectancies are considered to be derived from underlying cognitive structures.

Surprise plays an important role in the studies of Gelman (1972a, 1972b; Gelman & Gallistel, 1978). Results of her studies showed that very young children do appear to recognize the invariance of number. Gelman's tasks, however, focused on very small amounts, usually three or less. Her assessment also excluded a typical conservation transformation. Gelman (1972b) asserted that the standard Piagetian conservation task evaluates more than logical capacity, that it also tests control of attention, correct semantics, and estimation skills. She contended that children possess a logical system for manipulating number before they reach the stage of concrete operations.

In conclusion, the findings of these studies yield ambiguous results. While there is some evidence of superior performance at a younger age on
modified assessments when compared with traditional Piagetian tests, this is countered by objections that the two types of studies are actually assessing different skills. As L. Siegel (1978) indicated, few studies have directly compared nonverbal and verbal task performance. The importance of these studies lies in the discovery and definition of the quantitative abilities of young children who, as Gelman continues to remind us, are more often described by their quantitative deficiencies.

Mathematics Teaching and Learning

Theorists in the area of early childhood mathematics education disagree about whether the ability to conserve is necessary for the development of number concepts. However, most say that, with or without conservation, young children need active experience with beginning number concepts.

Several investigators (Farnham, 1975; L. Siegel, 1971; Suydam & Weaver, 1975) have noted that research information on how young children develop an understanding of mathematical concepts is incomplete. Gelman and Gallistel (1978) felt that the identification of a theoretical framework for mathematics concept development would be facilitated by more complete data on what young children can do cognitively. L. Siegel (1971) suggested that because there has been no attempt to integrate the findings of studies about specific aspects of the development of quantitative concepts in children, little is actually known about the sequence and manner of development of these concepts.

Cruickshank, Fitzgerald, and Jensen (1980), stated that mathematics instruction is generally based upon the logical structure of mathematics. In other words, mathematical concepts are taught according to a sequence based
upon a hierarchy of skills. Counting is followed by addition, and subsequently by subtraction, multiplication, and division. However, they cautioned that the presentation of mathematics as an organized logical structure does not assure understanding by young children. Young children's learning may not follow a structure which has been organized according to such a hierarchy. Consideration must be given to the integration of the logical and psychological aspects of learning mathematics.

Piaget's theory of cognitive development outlined several distinct stages through which children progress in a fixed sequence. Each stage has specifically identified characteristics. The age at which a child reaches a particular stage may vary, but the sequence of progression does not. According to Piaget, children's activities are the basis of their learning. Understanding and development occur as the child interacts with the environment, taking in new information (assimilation) and using the new information along with what he already knows to form new ideas and to tackle new problems (accommodation). Children's errors are viewed as a result of their level of development. A response is not really incorrect, it is simply an answer to a question which is perceived differently by the child than by the adult who posed the question.

In discussing the implications of Piaget's theory for teaching mathematics, Copeland (1974) emphasized the need for activity-oriented programs which allow children to explore and to manipulate objects. He contended that first grade and kindergarten math should be devoted to "readiness activities" since the ability to conserve quantity is not generally attained by this time, and conservation is viewed as necessary to the understanding of number. In general, Copeland felt that elementary math instruction should involve more
work with concrete materials and less with mathematical symbols. Copeland was supported by Green and Laxon (1978) in the interpretation that until a child has the concept of conservation he is not capable of any truly quantitative reasoning, nor of performing mathematical operations with real understanding. Ginsburg and Russell (1981), however, claimed that success at conservation was not necessary for success at other mathematical tasks.

Leymoyne and Favreau (1981) have reported that children at Piaget's concrete operational level achieved greater success in arithmetic than children at the preoperational level. In addition, they found that, in solving arithmetical questions, preoperational children resorted to memory more often than did concrete operational children who displayed greater understanding of basic numerical properties. However, Leymoyne and Favreau also noted that many of the preoperational children in their study were able to perform well in addition-and subtraction problems. They questioned the relevance of concrete operational thought as a competence factor related to mathematical learning.

Dienes (1969, 1973; Dienes & Jeeves, 1965) viewed children's understanding of math concepts as a three-stage evolutionary process. The first stage involves unstructured play with materials. Dienes saw this as the time when the rudiments of future concepts and understanding are developed. During the structural activities stage, experiences are designed to be "structurally similar" to the concepts to be learned. This stage is viewed as laying specific groundwork for later concepts. Finally, during the practical stage the concept has become fixed in the child's mind and the child is able to apply his knowledge to specific situations. According to Dienes, not only must learning be based on experience, but also the child must be exposed to a variety of situations involving the concept in order to ensure a complete understanding.
Ginsburg (1977) theorized that quantitative concepts begin to develop with very young children and continue to develop from ages two through six. Ginsburg and Russell (1981) described the young child's quantitative knowledge as beginning with unschooled, non-numerical skills which are based on perceptions. At about age three the child's knowledge progresses to a level at which the child spontaneously employs some form of counting procedure, often untaught. This stage progresses to a level of codified procedures for doing written mathematics when the child receives formal instruction in school. Understanding of these skills is viewed as dependent upon the child's assimilation of the new skills into his existing framework of informal mathematical knowledge.

Gattegno (1963, 1970) also stated that young children progress through a long phase of "qualitative arithmetic" during which the mental structures and experience which form the basis of numerical arithmetic are developed. He cautioned that teaching amounts without the child's having had the appropriate quantity experiences is a fruitless endeavor.

The emphasis of Gelman's investigations (1972a, 1972b; Gelman & Gallistel, 1978) has been on identifying the number abilities of young children and discovering the cognitive processes and strategies they use. She has demonstrated that when the numbers used are sufficiently small, children as young as two display a strong understanding of number which is independent of irrelevant perceptual information. Additionally, her studies have shown that three-year-olds, and even some two-year-olds, have rudimentary counting abilities. She has described five principles which underlie the ability to count. The "one-one" principle involves recognition that each object in a collection must be assigned a tag (name) and only one tag may be assigned to each
object. The stable-order principle requires that the tags must be arranged in a repeatable order, and that the number of tags must be equal to the number of objects in the array. In the cardinality principle, the tag applied to the final object in an array must represent the number of objects in the array. The abstraction principle requires that the child recognize that the first three principles may be applied to any array or collection of entities. Finally, the order-relevance principle requires that the child understand that the order in which objects in an array are tagged is unrelated to the number of objects in the array.

Some concerns have been raised by Miller (1976) and Sternberg (1980) who suggested that Gelman may credit too much to the preoperational child. Sternberg stated that Gelman and Gallistel's "pioneering" research ought to be viewed with cautionary skepticism. He cited the need for further study which would relate Gelman's theories to psychological realities.

L. Siegel (1971) investigated the sequence of development of certain quantitative concepts in young children. Her findings indicated that children understand equivalence and magnitude differences at approximately the same point in concept development. In later studies (1977, 1978), however, she found that it was easier for children to judge magnitude differences than equivalence. Siegel also found that the ability to recognize equivalence develops slightly earlier than the ability to conserve. It should be noted, however, that the conservation assessment used by Siegel was not a standard Piagetian task. The seeming contradictions in Siegel's findings provide an example of the difficulty of comparing results of assessment techniques which may be measuring different abilities. Although children may display an understanding of a concept, they may not apply this knowledge with the same facility to a different task.
L. Siegel (1982) has also investigated the perceptual and linguistic factors which she feels influence the development of quantity concepts. She described two sequential processes in the young child's abstraction of number. First, the child must recognize number as an independent dimension; then, the child must learn that cardinal number means exact numerical correspondence. Siegel suggested that a predominance of nonlinguistic operations exists in early quantity concepts, and that language plays an increasing role in the solution of tasks involving elementary notions of quantity.

McLaughlin (1981) questioned Siegel's finding that preoperational children are able to make judgments of relative numerosity. According to McLaughlin, the format of Siegel's assessments, which combine number with density and length, makes it impossible to determine whether the children's responses were based on perceptual factors (density, length) or on number. McLaughlin's findings indicated that children as young as three can use perceptual cues to judge number, but that only when they near the concrete operational period can they recognize that perceptual cues are unreliable. McLaughlin claimed that the results of her study cast doubt on the conclusions reached by Siegel (1971, 1977, 1978).

According to Zimiles (1963), the concept of quantity exists for the child prior to the concept of conservation. Children's earliest views about quantity are based exclusively on perceptual cues and are therefore somewhat ambiguous. Zimiles felt that the young child's emerging ability to count aids the child in overcoming his or her perceptually-dominated concept of quantity. It is Zimiles's opinion that children's superior performance on nonverbal conservation tasks is due to the nature of those assessments; they require the child to respond to situations of quantity and are not complicated by ambiguous relational language which is fundamental to standard Piagetian assessments.
In summary, the information that has been gained from studies of young children's quantitative abilities is not at all clear. Sternberg (1980) has called for researchers to direct their attention toward the characterizing of quantitative skills of children of different ages through longitudinal studies. The importance of learning mathematics through experience cannot be denied. But the important question of whether quantity conservation in the Piagetian sense is a prerequisite for understanding number is unresolved. Certainly it is necessary to address Gelman's challenge to identify the abilities possessed by the preoperational child. Only in this manner will it be possible to develop approaches to teaching mathematics which take into account both the logical structure of the subject and the cognitive abilities of the student.

Language Perspective

What kind of meanings do young children attach to quantity and relational words? Are their meanings consistent with adult usage or do young children use and respond to these words in a totally different manner which reflects their experience and their perceptions? These are crucial issues if we are to judge children's cognitive abilities by their responses to comparative questions and by their explanations of their comparative judgments.

Much of the controversy about children's quantitative abilities is due to the central role that language plays in assessing their skills. According to Palermo (1973), it is often assumed that children comprehend comparative terms. However, as L. Siegel pointed out (1978), a substantial body of knowledge indicates the existence of significant deficiencies in the young child's understanding of relational terminology.
Many studies have investigated the young child's understanding of the terms *more* and *less*. Donaldson and Balfour (1968) and Palermo (1973, 1974) have found that an understanding of *more* develops before an understanding of *less*. Several researchers claimed that young children use the term *less* synonymously with *more* (E. Clark, 1973; H. Clark, 1970; Donaldson & Balfour, 1968; Donaldson & Wales, 1970). According to Donaldson and Balfour, many young children tended to respond as if they knew the word *less* and that the word referred to quantity, but at the same time they did not differentiate *less* from *more*.

E. Clark (1973) has suggested a developmental sequence in the acquisition of the two terms. First, the child uses *more* and *less* in a nominal sense to mean amount or a quantity of, and the comparative nature is not understood. Next, the child uses both *more* and *less* to refer to the extended end of the scale. When asked to point out which tree has more or less apples on it, the child will always indicate the one with more because it best exemplifies a tree with some (quantity or amount) on it. In the last stage *more* and *less* are used comparatively in their contrastive sense. Only at this stage does the child differentiate between the two terms.

Some investigators have questioned whether children actually do equate *less* with *more*. Wannemacher and Ryan (1978) found no evidence to support the less-is-more theory. They identified a continuum of skills in the understanding of *less*. At the first level *less* is never judged correctly. At the second stage the child's judgment of the term is unstable and susceptible to perceptual cues. Finally, the child is consistently able to judge *less* correctly. Harasym et al. (1971) also found no evidence for the less-is-more theory. In fact, children in their study tended to respond to *more* as if it meant *less*. 

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According to Grieve and Dow (1981), the young child's ability to comprehend more appears to be fairly secure. But they cautioned that young children may use a variety of non-numerical bases for judgments about more. Unlike an adult's quantity-based judgment of more, a young child's interpretation of the term may be based on the length, density, or appearance of the objects being compared.

Brush (1976) distinguished between young children's nonquantitative and quantitative use of the term more. She reported that young children will often use more in a nonquantitative sense to describe the reappearance of an object. For example, the child who reopens a picture book and says, "more train," is noting the recurrence of a familiar object and is not using more in a quantitative sense. Brush also noted that many young children display inaccurate quantitative notions of the word more, by using the term to mean any difference in quantity, rather than a difference in a particular direction.

In a discussion of children's apparent confusion with the term less, Donaldson and Balfour (1968) suggested that children's experiences with situations in which someone says, "That's too much, give her less," may lead the young child to conclude that less means, "She still gets more, just not as much!" It has also been suggested that because less is unknown to the child, a random choice of the larger amount is made. As L. Siegel (1977) indicated, young children are more likely to describe the larger amount than the smaller.

Further evidence of the controversy which surrounds this matter can be seen in the following four sets of results. In a study using the terms more and same, LaPointe and O'Donnell (1974) reported that tasks involving more were easier than those of equivalence. Laxon (1981), however, found that more was no easier than same. Griffiths et al. (1967), noted that same was used by the
children in their study significantly less often than more and less. Sarro (1980), however, claimed that more and same are understood prior to less.

One important factor in these studies is that, for the most part, they have measured children's responsive language. Cocking and McHale (1981) noted that language comprehension tasks are performed more accurately than language production tasks by four- and five-year-olds. Griffiths et al. (1967), reported that children may understand the meaning of relational terms but may not use them spontaneously. In contrast, Ehri (1976) claimed that children may produce comparative forms even though they do not comprehend their full meaning.

Griffiths et al. (1967), advised that greater attention should be given to whether elicited or spontaneous responses are used in assessments. Laxon (1981) has looked at how children respond to different types of questions when making judgments about quantity. Her findings indicated that the ability to produce correct manipulative responses is acquired earlier than the ability to make yes/no judgments. She stated that the way in which children are asked to respond to instructions given verbally (i.e., whether they are asked to perform a manipulation or to make a yes/no judgment) is an important factor in assessing children's quantitative skills.

Research findings on young children's relational language leave many questions unresolved. First, does the young child comprehend the quantitative question he or she is asked, in the manner in which it is intended? Or is the child responding to a totally different question based on his or her interpretation of the relational terminology used? Second, does the method of assessment require the child to respond nonverbally or to produce comparative language? Different levels of results should be expected from studies of
responsive and productive language. Third, what is the language used by the examiner in eliciting relational language? Methods of assessment which provide models of relational language through the examiner's questions should be expected to produce different results from techniques in which the examiner refrains from using such language.

Clearly, more precise information is needed about the development of quantitative and comparative language in young children. More explicit definitions of the terms understanding and comprehension as they relate to responsive and productive language might clarify seemingly contradictory findings. Smith (1980) suggested that a goal for future research should be to test specific models of how young children answer quantitative questions. Certainly, there appears to be a need to organize the existing information on children's quantitative and relational language. In this manner it may be possible to identify more accurately the young child's linguistic abilities and to relate them to appropriate mathematics teaching and learning strategies.

Summary

Theories which attempt to describe young children's language and understanding of quantity comparisons, by necessity, must draw from research in three different disciplines. But this is also part of the problem. A study which is rooted in one discipline tends to have a different focus and purpose than a related study in another discipline. The lack of communication among the disciplines has led to research results and theories which are difficult to synthesize into a useful body of information about the linguistic and cognitive abilities of young children. According to McCune-Nicholich (1981), despite the promise of the early seventies, little progress has been made toward this goal.
The extent of interaction and overlap between cognitive and linguistic functioning is still not clear. Also unresolved is the important issue of whether young children's use and understanding of relational terms are justifiable criteria for judging their cognitive abilities.

This section has examined the three areas which form the basis of the study of young children's language and understanding of quantity comparisons: (a) the assessment of cognitive skills such as the ability to conserve number, (b) the development of understanding of math concepts, and (c) language skills which relate to quantities and comparisons. The following section describes studies which have looked specifically at language influences on mathematics development. It examines the language of math itself, and the problems that can occur when terms are introduced which either have a specific math-related meaning that may differ from the child's general usage of the terms, or which are inappropriate for the child's level of cognitive and linguistic functioning.

Implications of Language in Learning Mathematics

According to Pollak and Gruenewald (1978), math, more than any other subject, requires a basic language and conceptual foundation. Much has been written recently about the role that language plays in mathematics learning (Aiken, 1972; Austin & Howson, 1979; Fell & Newnham, 1978; Hanley, 1978; Love & Tahta, 1977; Monro, 1979; Nicholson, 1977, 1980; Novillis, 1979; Preston, 1978). Of the issues that have been raised in these articles, one of the most important is that the language of mathematics differs considerably from the child's natural language. Watts (1944) felt that mathematics has devised a highly technical language of its own, a language which is completely abstract.
Aiken (1972) described mathematics as a specialized language which differs from social English in that it has a high conceptual density factor, reflected by limited redundancy. The language of math is precise, compact, and specific. Pollak and Gruenewald (1978) stated that math operations require that the student understand a logical thinking language which is different from social usage. E. Clark (1973) described the role of language in early math instruction:

in the mathematics classroom the teacher uses language when he teaches new math content . . . the child must bring meaning to the words being said in terms of his current meanings for spoken words and the total situation in which the words are used . . . young children do not appear to have full meanings for common dimensional and relational terms (p. 28).

Pollak and Gruenewald also stressed the importance of the teacher's using language which is commensurate with the student's level of understanding and usage. According to them, if the teacher uses a word in math instruction which is not present in the child's language repertoire, the student may respond in a rote fashion but be unable to use the concepts in a problem-solving situation. Fell and Newnham (1978) stated that a major implication of the role played by language in math education is that, to a large extent, children's understanding of mathematical concepts is judged by their ability to use the symbols of the language, to tell us they understand.

Monro (1979) identified three classes of words that are used in math communication. First, are words that are defined in normal usage and that preserve this meaning in a math context. Second, are words which occur exclusively in a math context and as such they may not be part of children's linguistic repertoire. Third, are words which occur in both normal and math usage, but the words have different meaning in the math context (e.g., difference, half, set). When this type of word is used in a math context its
meaning is specific, while it is usually defined more loosely in ordinary usage. Monro claimed that this last group of words is most likely to cause confusion for the young child who may be totally unaware that a familiar word is being used in a different sense.

In order to increase the effectiveness of instruction, Novillis (1979) felt that teachers should be aware of the range of meanings that children at a certain age can have for mathematical terms. According to Preston (1978), normal language development and vocabulary ought to be matched to mathematical language and symbolism in a planned and unified way.

While many have described their feelings on the importance of language in mathematics education, few research studies are available to give specific information and direction. Information on children's knowledge of counting words has been provided by Fuson, Richards, and Briars (1982), by Fuson and Hall (1981), and by Gelman and Gallistel (1978). Their findings indicated that many two-year-olds know the first few number words and that knowledge of number words improves considerably with age. Saxe (1981) noted that the child's progress in mastering the number-word sequence extends beyond the preschool years. In his study of adults who suffered cortical injury, Saxe (1981) found that number operations and number words are not necessarily linked to cognitive functioning. An adult can understand number operations yet be unable to represent these operations with conventional language. Conversely, the person can be facile with the use of number words yet be unable to understand numerical operations. It is not clear whether Saxe's findings with adults may be appropriately applied to the development of young children. Saxe felt that a child who is having difficulty with the development of one of the aspects of number competence may have difficulty with the other as well.
In a study of children's responses to verbal and nonverbal cues presented in a set comparison task, Sarro (1980) found that the child's implied interpretation of relational terms was often inconsistent with his ability to explain the meaning of the terms. Sarro noted qualitative differences between child and adult use of the words more, less, and same. The differences are related to, "an independence that exists between the child's nonverbal and verbal responses to relational terminology" (p. 87). Sarro believed that this independence is reduced when the child acquires "adult" meanings for relational terminology.

Cottrell (1967) investigated a number of factors, emphasizing language, which might be associated with underachievement in the arithmetic concepts and problem solving of third grade students. Auditory-vocal skills and an overall language score were found to correlate significantly with arithmetic concepts achievement.

By recording children's language as they discovered math concepts, Clarkson (1973) concluded that children talking together can discover and describe important mathematical concepts. He noted that the situations most commonly used for math learning do not promote, and often even preclude, conversation between children. Thus, children may actually be deprived of the opportunity to develop mathematical language skills.

Nesher (1972) looked at whether the teaching of mathematics could be approached as the teaching of a second language. She also investigated possible connections between the language of arithmetic and the ordinary language acquired spontaneously by the child. Her findings indicated that the language of arithmetic is not the same for children as their ordinary language. Nesher saw the language of arithmetic not as an extension of a child's spontaneous language, but rather as a shift to another system entirely. As
such, she viewed the language of arithmetic as a kind of foreign language and considered the similarity of words between the two languages as a potential source of confusion for the child. She stressed the need to create an instructional environment in which children can have experiences that call upon them to use the language of arithmetic.

In an investigation of children's use of language in developing mathematical relationships, Farnham (1975) distinguished between reproducing language (words which a teacher requires the child to give back) and producing language (words used spontaneously by the child). Farnham felt that there was too great an emphasis on the reproduction of language in mathematics instruction. He observed children's use of "folk" language in mathematical thinking and stressed the importance of using language as a means of developing math understanding and creating mathematical thinking.

L. Siegel (1977, 1978, 1982) has studied at length the relationship between children's linguistic skills and their quantitative concepts. Her findings (1977) indicated that the child's understanding of relational terminology is acquired gradually and depends on the cognitive complexity of the operations required for comprehension. It is interesting to note that many children in Siegel's study interpreted big (used in the study as a synonym for more numerous) as referring to a longer row containing fewer items. Siegel found that even when the child had the appropriate language available, the ability to produce it was determined by the cognitive operations required.

In her discussion of the perceptual and linguistic factors that influence the development of quantity concepts, L. Siegel (1982) described several of the investigations she had conducted in studying the relationship between language and thought in young children, and the relationship between young children's
quantity concepts and their understanding of certain words related to quantity. She noted that significant numbers of three- and four-year-old children passed the concept assessment, yet failed the language production assessment. Siegel concluded that, for the preschool child, concepts of numerical equality and inequality are learned before the relevant relational terminology. Additionally, she contended that language and thought function independently in the young child and, as the child develops, concepts and language tend to become more related. On the basis of her findings Siegel cautioned that measurements of cognitive skills which rely on the understanding of language or the production of linguistic responses will underestimate the cognitive abilities of the young child.

In conclusion, there is general agreement that language plays an important role in the learning of mathematics concepts. Monro (1979) felt that many approaches to math education largely ignore the need for allowing the child to comprehend and to use concepts and relations within his own language structure. An early childhood math curriculum which stresses mathematical symbolism and terminology without providing sufficient experiences for the child to develop an understanding of the symbols' meanings may be inappropriate for the child's level of cognitive and linguistic functioning.

Demographic Influences

As we have seen, there is considerable controversy about the roles played by cognitive development and language development in the ability of children to make and to understand quantity comparisons. However, it has also been suggested that there are background or demographic factors which influence both cognitive and language development. By extension, therefore,
these influences might be expected to show up in a study of quantity comparison abilities.

There is a voluminous literature on the subject of demographic influences, especially concerning sex-related differences. There are also traditional perceptions of influence which, in some cases, have led to stereotyping. Such stereotypes are not easily abandoned and unfortunately may influence parents' and teachers' expectations of children's abilities.

A detailed discussion of research supporting and refuting these perceptions is not relevant to this study, which is concerned mainly with identifying the ability of children to produce and to respond to quantity-comparative language. As part of that principal objective, however, this study also examined the children's abilities for evidence of demographic influence. This section, therefore, presents a brief overview of the literature related to the three areas selected for examination: sex, race, and the education of the child's mother.

Sex

Traditionally, young girls are perceived to outperform young boys on academic tasks. Young girls are also generally characterized as having superior verbal skills. However, mathematics has long been viewed as an area in which males outperform females.

In a review of mathematics learning and the sexes, Fennema (1974) found no significant difference between the mathematics achievement of girls and boys at the preschool or early elementary level. Stanley, Keating, and Fox (1974), also found no significant difference in math aptitude between the sexes, to age eleven. According to Ginsburg and Russell (1981), who found a
virtual absence of sex effects in their study results, girls do not begin their academic careers with inferior mathematics abilities.

In reviewing studies of conservation of number, Calhoun (1971) reported that most studies have shown no significant sex difference in conservation responses. Studying different types of conservation tasks in an attempt to discover dependencies between cognitive and linguistic operations, Moore and Harris (1978) reported that no sex difference was observed on any of the measures used. Martin (1951) found that girls outperformed boys on tasks of number ability, while boys demonstrated superiority on tasks of spontaneous expression of quantity. Of the children in his study, Martin noted that, although girls were more loquacious generally, boys used more quantity-related words.

Race

In a study of social class and racial influences on early mathematical thinking, Ginsburg and Russell (1981) found a lack of race-related differences between middle-class Black and middle-class Caucasian children. Their findings in a second study (1981) indicated few racial differences at either middle- or lower-class levels. Ginsburg and Russell concluded that early mathematical thought develops in a robust fashion regardless of social class and race.

A study of children's language differences, conducted by Schachter (1979), investigated the influence of the mother's language on the child's language development. According to Schachter, the results clearly indicated that differences in verbal productivity were related to maternal education and not to race; that is, Black mothers with educational and economic advantages
speak just as much to their toddlers as do Caucasians with similar advantages. In a discussion of children who speak a non-standard dialect, Adler (1979) stressed that children's cognitive abilities must not be considered deficient simply because they are expressed in a different language format.

Language of the Mother

Investigators have used different measures to define socioeconomic status. This lack of uniformity in definition has made unreliable the generalization of differences between children of different socioeconomic levels. Recent studies (Adler, 1979; Schachter, 1979) have chosen to use the mother's education as the criterion for grouping children. Schachter (1979) explained her use of number of years of maternal education as a definition of advantage, in the following way:

it was felt that this aspect of social class status had the greatest impact on the child, by virtue of the association between maternal education and access to adequate child development information (p. 14).

Schachter claimed that in her study other social class indices, when available, correlated highly with mother's education. The mother's educational level was found by Helton (1974) to be the most effective predictor of language behavior of several factors studied, although Adler (1979) cautioned that its predictive ability was still fairly weak. According to Adler, there is simply no one measure or combination of measures that is a strong predictor of language behavior. Adler also cautioned that in measures of years of schooling completed, no distinction is made for differences in the quality of education received.

In their review of children's language and reading abilities, Anastasiow, Hanes, and Hanes (1982) asserted that lower-class children have the competen-
cies but lack the training that middle-class children have had. Ginsburg (1972), Labov (1970), and Rosen (1972) claimed that lower socioeconomic language can deal adequately with logical and abstract thinking. Martin (1951) noted superior quantitative expression in children from upper occupational groups, but greater productivity of language in children from lower occupational groups. In general, Martin's findings indicated that children of upper occupational groups were slightly superior to children of lower occupational groups in some aspects of quantitative expression.

Ginsburg and Russell (1981) found no social class difference in children's early mathematical thinking. They claimed that at most there exist some insignificant trends favoring middle-class children over lower-class children. According to Ginsburg and Russell, in most cases children of both social classes demonstrated basic competence and similar strategies for solving the various tasks used in their study. Two areas where significant social class differences were noted at the preschool and kindergarten levels were on tasks of conservation and equivalence. Ginsburg and Russell concluded that at the four- and five-year age levels there are few social class differences in the basic aspects of mathematical thinking. It was their contention that, "while culture clearly influences certain aspects of cognition (e.g., linguistic style), other cognitive systems seem to develop in a uniform and robust fashion despite variations in environment and culture" (p. 52). From a language viewpoint, however, Schachter (1979) reported that:

in reviewing the findings for all the variables under study, socioeducational status, race, age, and sex, it becomes apparent that the variable with by far the greatest impact on mother's speech is socioeducational status. Educated mothers, as compared to less educated mothers, seem to provide their young children with very different kinds of early verbal environments and these differences may well account for the disparities in the later school performance of their children (p. 127).
Conclusion

The literature suggests that for young children, quantitative language may be confusing, ambiguous, and even unfamiliar. Studies also imply that the development of math concepts arises from children's varied experiences and informal explorations, and that very young children are, in fact, able to solve quantitative problems if the amounts are sufficiently small. However, traditional assessments of the young child's mathematical concepts, which use specific relational terminology, may unfortunately prevent the child from demonstrating his or her understanding of the concept. As Donaldson and Wales (1970) indicated, children's failure to respond appropriately to quantity comparison tasks may be as attributable to the structure of the child's language as to other aspects of his or her cognitive structure.

The literature also reveals two basic problems. The first is the lack of a clear view of the processes involved in the development of a child's abilities to make and to understand quantity comparisons. This can only be solved by the integration of the study of young children's linguistic and cognitive abilities as they relate specifically to the learning of mathematics. Within this problem, and contributing to it, lies a second problem: the absence of a definition or description of the abilities possessed by children at the preoperational level. The curricular implications of the second problem are more immediate. The literature tends to characterize children at this stage by their abilities. Without information on what children are able to do, curricular decisions are often based on assumptions, and as the literature indicates, there is very little that can safely be assumed. It is this area of investigation which is the basis for the current study.
CHAPTER III

DESIGN AND METHODOLOGY

The purpose of this study was to examine young children's production and understanding of quantity-comparative language. The study consisted of several objectives: the measurement and description of productive language, the measurement and description of responsive language, the identification of the relationship between productive and responsive language, and the identification of relationships between various background attributes of the subjects and their productive and responsive language abilities. While each of the objectives had a slightly different focus, they were all designed to provide results which could then be examined, (a) for curricular implications, by comparing the actual language abilities of the children in this study with the language used in typical kindergarten math programs, and (b) for observable patterns and trends which might clarify the findings of previous research.

The measurement of both productive and responsive language required considerable attention to detail for several reasons, chief among which were the ease of inadvertent biasing of the results and the difficulty of motivating responses from children of this age without, at the same time, contaminating the results. The study designs described below have resulted from a series of pilot designs which were tested at different times, with varying numbers of subjects. The observations and results of each pilot test were used to refine the procedures to reduce possible bias and to improve motivation for response.
Subjects

The subjects for the study were 97 children who were within the six month age range of 4 years 9 months to 5 years 3 months, on April 1, 1982. All subjects were intending to enter a formal kindergarten program in the Fall of 1982. Children for whom English was not the dominant language at home or for whom some form of teacher referral for assessment had been made were excluded from the study.

All subjects were attending some type of early childhood facility in urban and suburban Kalamazoo. Initially, a total of 429 children were identified as meeting the criteria for the study. These children represented 100% of the Head Start facilities, 90% of the child care facilities, and 95% of the nursery/preschool facilities within the designated area. All facilities in the region were contacted. However, one nursery school and one child care facility were eliminated from further consideration due to time constraints of the study, and one other child care facility chose not to participate in the study.

A proportional stratified sampling technique was used to ensure adequate representation of children from the three different types of facilities. A sample of children was chosen randomly from each of the three strata so that each stratum was represented proportionately in the study. To ensure equal numbers of boys and girls within each stratum sample, each of the three strata were split according to sex prior to random sampling. Boys and girls were selected independently.

The selection was accomplished by the use of a computerized random number generator which produced integers within a specified range. Each child was assigned an identifying number to enable selection.
A total of 100 children were selected randomly in the following strata: 22 children from Head Start facilities (11 males, 11 females), 32 children from child care facilities (16 males, 16 females), and 46 children from nursery/preschool facilities (23 males, 23 females).

A letter describing the study activities (Appendix A) was sent to the parents of each child selected for the study. At the bottom of the letter was a consent form which the parents were asked to sign and return. The consent form also included a request for some additional background information. Of the 100 letters sent out, 97 consent forms were returned. A follow-up inquiry of the three unreturned consent forms indicated that one of the children no longer attended the facility due to illness in the family, and that the two other parents preferred that their children not participate in the study. A total of 47 boys and 50 girls took part in the study.

The interviews took place at the early childhood facility attended by each child, except for one which was conducted at the child's home. Each interview was conducted by the author in a quiet setting and lasted approximately 15 minutes. The study took place over a five-week period from April 19, 1982 to May 20, 1982.

Procedure

Two assessment tests were administered to each subject: one for productive language and one for responsive language. Both tests were administered at the same sitting, with the productive assessment always preceding the responsive assessment.
Productive Language

Assessment Design. An introductory productive language activity was designed with two purposes in mind: first, to provide an opportunity for the examiner to establish rapport with the child in a play situation, and second, to help focus the child's attention on quantity comparisons. In the introductory activity, the examiner showed the child a Cookie Monster puppet and asked whether the child knew who it was. In the pilot study, children's responses indicated widespread recognition of the Cookie Monster character. After a discussion between Cookie Monster (examiner) and the child, the examiner set out two paper plates and six identical small cookies, four on one plate, and two on the other. Cookie Monster said, "I really like cookies and I'm very hungry." The child was then asked which plate of cookies he or she thought Cookie Monster would like to have. When the child indicated a plate the child was asked to explain why that plate was chosen. Then Cookie Monster said, "I really like cookies but I've been eating them all morning and I'm really full. Right now I'm not very hungry." The child was asked to indicate the plate of cookies that Cookie Monster would like to have now, and to explain why. The child was then asked if he or she would like to have Cookie Monster's cookies and was offered the six small cookies to eat. At no time did the examiner use comparative language.

Following this activity, the 10 productive language tasks were introduced. The first task used paper plates as in the introductory activity, in an attempt to continue the child's focus on comparisons. The remaining 9 tasks used a display mat format (a 9"x12" piece of heavy tan paper divided in half by a heavy black vertical line).
For the first task, the examiner set out the paper plates and two identical Paddington bears (2½" tall) and indicated by pointing that, "This is this bear's plate and that is that bear's plate." Two natural-colored, one-inch wooden cubes were placed on one plate and three identical cubes were placed on the other plate. The child was asked, "What can you tell me about these two groups of blocks?" If no response was given a second probe was made: "Tell me what you see." Additional probes of, "What else can you tell me about the blocks?", and, "Can you tell me that another way?", were used to encourage the child to make comparisons in different ways.

In the pilot tests the presence of the bears had been observed to be a motivating device in that it permitted assignment of ownership of the cubes to a bear. It also eased the task of the examiner in probing for response by permitting reference to a particular bear, and allowed the examiner to use ownership-related language rather than quantity-related language. Such additional probing, however, was only used if the child had not focused on quantity comparisons with the initial questions.

When the child appeared to have completed his or her descriptions and did not respond to a subsequent probe, the examiner moved on to the second task. The plates were removed from the work area and were replaced by the display mat (which was also used for the remaining tasks). One side of the mat was described as belonging to one bear, the other to the second bear. Five blocks were set out on one side and two blocks on the other side (for example). The examiner asked the same questions used in the first task.

This procedure was continued throughout the remaining eight productive language tasks. In each task various numbers of blocks were set out so that in some tasks the numbers of blocks were equal and in other tasks they were
unequal. The number of blocks on each side ranged from two to five. The order of presentation of the tasks was predetermined and randomly generated, as was the number and spatial location of blocks on each side. However, each particular task was the same for all subjects. Three of the tasks dealt with equality and seven dealt with inequality.

The entire productive language assessment was tape recorded. Additionally, the examiner used an observation sheet for each child (Appendix B). To establish reliability and objectivity, the tapes and observation sheets of 40 randomly selected subjects were also assessed by an independent judge. An agreement of 90% was found between the assessments of the examiner and the independent judge.

Since very few studies have focused on the young child's spontaneous production of quantity-comparative language, it was not possible to use an established instrument for this assessment. Instead, it was necessary to extract techniques from somewhat relevant studies (Ehri, 1976; Estes, 1976; Martin, 1951; L. Siegel, 1977, 1978) to devise a method which would encourage language production. The method was modified several times on the basis of results of the pilot tests. Validity of this measure is indicated by the fact that the pilot study did elicit the spontaneous production of natural language.

Two factors were observed to affect markedly the production of comparative language in the pilot studies. The first was the difficulty of focusing the child's attention on comparisons of quantity, rather than upon the spatial relationship of the objects, geometric form, and the like. The second was the possibility that subjects might learn comparative language from the examiner. In one of the pilot tests, children were much more likely to focus on comparisons and to produce comparative language in the productive
assessment when the responsive assessment was given first. This was to be expected, since the responsive test provided verbal quantity-focusing cues from the examiner. Unfortunately, however, the child could also have learned comparative language from the examiner. In at least one published study related to productive language (L. Siegel, 1977), this potential source of bias appears to have been overlooked. The two problems were circumvented by conducting the productive assessment first (to prevent subject learning) and by developing the pre-activity with the puppet (to focus on quantity comparisons).

**Scoring and Measurement.** One of the goals of the study was to describe the language used spontaneously by the subjects. Spontaneous language was collected from the tape recordings of the productive assessment and was reported in the form of a list of terms and phrases, ranked by frequency of use.

To facilitate measurement of the use of productive language, a scoring sheet was filled out for each subject (Figure 1). The sheet contains 10 rows, which correspond to the 10 tasks, and 3 columns, which correspond to the following pieces of information that were extracted from the tape recording, for each task:

A. Is a quantity-comparative response given?

B. If yes, is it an appropriate response?

C. Is more than one appropriate response given?

A score of 1 was entered in the appropriate column on the scoring sheet if the answer to a question was yes, and 0 was entered if the answer was no. In a given column, therefore, the sum of the entries could range from 0 to 10.

A child was considered to have given a quantity-comparative response if he or she indicated an awareness of quantity comparisons, verbally, in any
manner except by naming the amounts numerically. In other words, the child who said, accurately or not, "This is five and this is three," was not considered to have made a quantity comparison unless the child also made a comparison in some manner, such as, "This is bigger (or smaller, or needs more blocks, or has too many)."

Measurement of the degree to which children were able to make quantity comparisons was accomplished by determining a productive language usage score for each child. This score was simply the sum of the three columns on the scoring sheet. The score, therefore, reflected a child's ability to produce any quantity comparisons (column A), an accurate response (column B), and more than one accurate response (column C). Since three columns were
summed, the score could range from 0 to 30. The maximum score could only be achieved if a child was able to produce more than one appropriate comparison in all 10 tasks, while the minimum score resulted if a child was unable to produce any comparative language (correctly or incorrectly) throughout the assessment.

A second score was determined for each child. This was designed to measure only the extended level of language production, defined in this study as a child's ability to produce appropriate comparative language in more than one way for a given comparison task. This score is referred to here as the extended productive language score, and is the column C total (productive language scoring sheet, Figure 1) for the child. Extended productive language scores could range from 0 to 10.

The results of the scoring were presented in the form of range and median scores. This provided a description of a particular population of beginning kindergarten children in terms of their ability to produce any form of quantity-comparative language (conventional or natural). In conjunction with the list of terms used and their frequencies, the scoring information was examined for possible implications in kindergarten math programs.

Responsive Language

Assessment Design. The assessment consisted of 11 tasks. Each task used four cards, a reference card and three selection cards, on each of which were glued from two to five identical small poker chips. The test was designed to assess a child's ability to pick correctly a selection card, as a response to an examiner's question which included comparative language. The order of the tasks, the number of objects on each card, the order of the
selection cards, and the placement of the objects on each card were predetermined and randomly generated. The only constraint was that in each task there was exactly one correct answer possible. Each particular task was the same for all children.

As in the productive assessment the quantities used were limited to two through five. Gelman (1972b) found that children's performance with quantities was more accurate when the numbers were sufficiently small. Also, it is generally understood (Gibb & Castaneda, 1975) that amounts up to four and five are more easily recognizable than larger numbers and can often be named without counting.

In each of the 11 tasks the examiner instructed the child to look at the reference card, then to look at the other three cards and to, "pick the card which has (for example) more than this one," referring back to the reference card. If a child did not respond, the instructions were repeated in the identical manner. If there was still no response, the examiner went on to the next task.

Each task involved a different comparative term or phrase, however, all were related to equality or inequality. The terms assessed were:

- more than,
- just as many as,
- smaller number,
- less than,
- same number,
- not as many as,
- bigger number,
- equal to,
- larger number,
- fewer than,
- greater number.

The terms were chosen from a representative survey of current kindergarten mathematics programs and from consultation with several teachers of young children. Since no additional comparative term appropriate to this type
of assessment was generated in the productive section of the pilot study, the original list of 11 terms was not altered.

The subject's choice for each task was recorded on an observation sheet which contained all the preselected patterns (Appendix B). If the child gave no response or asked for an explanation of an unfamiliar term, the response was scored as incorrect.

The tasks of this assessment demanded relatively straightforward responses which could be recorded easily and objectively. However, to establish reliability of scoring and coding, an independent observer was present at 11 of the 97 interviews. The observer also filled out observation sheets for those interviews. A scoring agreement of 100% was found between the observer and the examiner.

Other studies which have used similar coding systems (Ginsburg & Russell, 1981; L. Siegel, 1976, 1978) have consistently reported high reliabilities. This assessment was based directly on the procedure used by L. Siegel (1976, 1978); modifications involved the use of physical objects glued to the stimulus cards (rather than Siegel's dots), and the presentation of more terms. The validity of this technique was indicated by its established validity in other studies.

**Scoring and Measurement.** The goal of the responsive language assessment was to determine the terms or phrases to which children were able to respond correctly and those with which children had difficulty (no response or incorrect response). The percentage of children who responded correctly to a particular term was determined for each term. This information was then used to rank the terms and phrases. In addition, the number of correct responses given by a child in the 11 tasks was considered the child's responsive
language score. The range of possible scores for any subject was from 0 to 11. The language scores were used in an analysis of relationships between responsive and productive language, as described in the following section.

Analysis

Relationships Between Productive and Responsive Language

The first relationship to be examined was that between the level of a child's responsive language and the level of his or her productive language. Each of the subjects had a responsive language score which could range from 0 to 11. Each subject also had an overall productive language score which, as described earlier, was the sum of scoresheet columns A, B, and C, for the 10 tasks. The range of possible scores for any subject was from 0 to 30.

Both language scores were considered to be interval measures, for two reasons. First, the difference between points on the scoring scales was meaningful and did not result simply from ranking (as with ordinal measure, for example). And second, a score of 0 did not necessarily imply a total lack of a particular language ability (as with ratio measure, for example). The subject may have had the appropriate language but may not have produced evidence of it under the conditions of the assessment.

A Pearson product moment correlation coefficient was calculated to determine whether a relationship existed between the children's responsive language scores and their overall productive language scores. The resulting coefficient was then tested for significance. The null hypothesis was that the population correlation coefficient was zero, and the research hypothesis was that the population correlation coefficient was different from zero. An alpha level of .05 was chosen for rejection of the null hypothesis.
In the second analysis, a Pearson product moment correlation coefficient was similarly used to determine whether a relationship existed between responsive language scores and extended productive language scores. An alpha level of .05 was chosen for rejection of the null hypothesis, which was, that the population correlation coefficient was zero.

Relationships Between Background Attributes and Productive and Responsive Language

The language scores were then examined for relationship with three different background attributes: the child's sex, the child's race, and the level of the mother's education. In each analysis of a particular background attribute, the children were divided into two groups (such as males and females, or Blacks and Caucasians). The language scores, thereby dichotomized, were examined for significant difference. Responsive scores were analyzed separately from productive language scores. In the latter case, it was the overall productive language score (the sum of scoresheet columns A, B, and C) of each child that was used (range of possible scores, 0-30).

Sex. Mean productive language scores were calculated for both males and females. A t statistic for independent groups was calculated and was used to test the research hypothesis that the mean scores of boys and girls were different (non-directional). A .05 alpha level was selected for rejection of the null hypothesis (that there was no difference in the mean scores of boys and girls). The same test was also applied to responsive language scores.

The use of the t statistic required the assumption that the independent samples were chosen randomly from a normally distributed population. Because the numbers of males and females in the study were almost equal (47
males, 50 females), the homogeneous variances assumption of the t test was not a consideration.

Race. Mean productive language scores were calculated for both Black children and Caucasian children in the sample. A two-tailed t test was again used to test the research hypothesis (non-directional) that the mean productive language scores of Blacks and Caucasians were different. The null hypothesis was that there was no difference in the mean productive language scores. Mean responsive language scores were tested in a similar manner.

However, since the sample sizes were quite different (78 Caucasians, 14 Blacks), the homogeneous variances assumption required by the t test merited serious consideration. According to Glass and Stanley (1970, p.297), whenever the variances of the two populations are different and the sample sizes are unequal, the probabilities of type I and type II errors can be quite different from what might be expected. While the sample variances were reasonably close (reported in Chapter IV), there was no way to estimate accurately the population variances.

To guard against possible misinterpretation of the t test results, a Mann-Whitney U test was also performed on the same data. The Mann-Whitney is a powerful non-parametric test of whether two independent groups have been drawn from the same population, and is often used when it is necessary to avoid the t test's assumptions (S. Siegel, 1956, p. 116). If the Mann-Whitney results supported those of the t test, then the implications of the findings could be examined with greater confidence. If the results of the tests did not agree, then any conclusions that could be drawn from the comparison of Black and Caucasian children's productive and responsive language abilities would have to be approached with caution.
The Mann-Whitney test was applied to the productive language scores of Black children and Caucasian children, and then to their responsive language scores. In each test, the null hypothesis was that there was no difference in the language scores of Blacks and Caucasians. The research hypothesis was that the scores of Caucasians were higher than those of Blacks. Since the Mann-Whitney is a one-tailed test with a directional research hypothesis, and the t test described above is two-tailed (with a non-directional research hypothesis), an alpha level of .025 (half the level of the two-tailed t test) was chosen in the Mann-Whitney for rejection of the null hypothesis.

Educational Background of the Mother. The educational background of each subject's mother was categorized as either high school diploma or less education, or associate's degree or more education. The former group also included children whose mothers had received some post-secondary education, but no degree beyond the high school diploma. Mean productive language scores were calculated for children in both groups. A two-tailed t test was then used to test the research hypothesis that there was a difference (non-directional) between the group means. An alpha level of .05 was chosen for rejection of the null hypothesis, that there was no difference in the mean productive language scores of the two groups. The same test was also applied to the responsive language mean scores of the two groups. Although the sample sizes were different (62 in the lower level of education of the mother and 34 in the higher), they did not appear to be sufficiently different to undermine the power of the t test, especially as there was no reason to infer a difference in the population variances.
Comparison of Children's Productive and Responsive Language with the Language of Typical Kindergarten Math Programs

The quantity-comparative vocabulary content of seven widely-used mathematics series, published since 1975, was examined at the kindergarten and first grade levels. Each series was reviewed for the following information:

(a) Were vocabulary or keyword lists included in the teacher's editions of the series at the kindergarten and first grade levels?

(b) If so, where were the lists located in the teacher's guide (book introduction, chapter introduction, or specific lesson)?

(c) Did the discussion of the lesson format make reference to any aspect of language related to the development of the math concept?

(d) A tally was compiled, by series, of the terms included in the vocabulary lists for both kindergarten and first grade. When a series did not contain vocabulary or keyword lists, a listing of related vocabulary was made through an examination of the lesson format descriptions in the teacher's editions. For those series which did include vocabulary lists, these lists were expanded, when appropriate, through an examination of the teacher's edition lesson format descriptions.

This information was then used as a basis for comparison of vocabulary content among the seven series. Comparisons were also made between the language abilities demonstrated by the children of this study (productive and responsive) and the vocabulary used in the seven textbook series.

The following chapter presents the results of the assessments and analyses of the data derived from the tests. The conclusions drawn from the analyses of these data and a discussion of their implications will then be presented in Chapter V.
CHAPTER IV

RESULTS

The presentation of the results is organized according to the goals of the study that were stated in Chapter I. The first section describes the results of the productive language assessment and examines the language produced by the children. Because the complete list of terms (presented in Appendix C) is quite lengthy, only the most frequently used terms are reported in this chapter. The children's responsive language performance is presented next. Following that is an analysis of the relationship between productive and responsive language, and analyses of differences between groups of subjects in their productive and responsive language scores. The final section of this chapter presents a comparison of the language abilities of the children of this study with the language of typical kindergarten math programs.

Productive Language

The productive language assessment consisted of ten tasks designed to elicit quantity-comparative language from the subjects: seven tasks were based on inequality and three were based on equality. The 97 subjects used 76 different terms or phrases (Appendix C) to describe larger, smaller, or equal amounts. It is important to note that a quantity-comparative term used by the subject was recorded, and is reported here, regardless of the appropriateness of its usage (inappropriate usage accounted for 5.6% of the instances of referral to larger amount, 5.9% of referrals to smaller amount, and 5.1% of referrals to equal amounts). This part of the study is concerned simply with
production of language. Appropriate production of language is reflected in the scoring described later in this section. Listed below are the three most commonly observed terms in each of the comparison categories.

There were 397 instances of referral to a larger amount, involving 23 different terms or phrases (Appendix C):

- more was used 260 times,
- a lot was used 38 times,
- most was used 27 times.

There were 332 instances of referral to a smaller amount, involving 33 different terms or phrases:

- only has (a number, such as 2) was used 70 times,
- less was used 37 times,
- just has (a number) was used 19 times.

There were 184 instances of referral to equal amounts, involving 20 different terms or phrases:

- both have (a number, such as 2) was used 58 times,
- same was used 53 times,
- both have the same was used 27 times,
- both have the same

Since seven of the ten tasks were based on inequality and thus could elicit language which referred to either a larger or a smaller amount, it was expected that about 30% of the children’s quantity-comparative utterances would refer to equality. In fact, substantially fewer of these utterances were observed. Only 184 instances of referral to equal amounts were noted, comprising 20% of the language produced in the assessment (when only appropriate utterances were considered, exactly the same percentage was found). Equality situations appeared to be considerably more difficult for children to describe than inequality situations.

When describing inequalities, where the focus could be on either the larger or the smaller amount, the children tended to focus on the larger
amount. However, the children were more inventive in their production of terms describing the smaller amount: 33 different terms were used to refer to the smaller amount, while only 23 different terms were used for the larger amount. This may be due to the fact that at least half of the terms describing a smaller amount contained some form of negation (Appendix C). Some children used the negative form of terms which refer to the larger amount (for example, not more than), while others used the more math-specific positive term (such as less).

Of all the comparative terms produced, more was used by far the most often — almost four times as often as the next most frequently-used term. In no instance was a negative term used to describe the larger amount.

When the children described smaller amounts or equal amounts, the most frequently-used terms involved numbers. For example, the term produced most often to refer to the smaller amount was only has two (or some other number). This was used almost twice as often as the more math-specific term, less. Similarly, both have two (or some other number) was the phrase used most often to describe equality. Reference to number never occurred as part of a description of a larger amount, although children did frequently identify the numeric value of larger amounts in addition to, or instead of, producing quantity-comparative language.

In describing equality, the children used same in a number of different forms, such as same, both have the same, same amount, and same number. With its variants, same was the principal term that the children produced. The more math-specific term, equal, was only used twice. This is particularly striking in view of the fact that 86% of the children responded correctly to the term equal in the responsive language assessment (described later).
In addition to examining the quantity-comparative language produced by the children, this study also developed a productive language scoring method. This was done, primarily, to enable the statistical analyses which are presented later in this chapter. The scores also permit an examination of the general level of the children's ability to produce quantity-comparative descriptions in their own language. In each of the ten tasks a score of 1 was assigned to a child if any quantity-comparative language was produced (column A of the productive language scoring sheet, Figure 1). An additional score of 1 (column B) was assigned if the language produced was appropriate to the task; for example, if the child not only said more but also used the term correctly in reference to the larger amount. Additionally, a score of 1 was assigned for each task (column C) if the child was able to describe correctly the quantity comparison situation in more than one way. Each of the three columns of a child's scoring sheet could, therefore, total to 10.

An overall productive language score for a child was determined as the sum of the three column totals, and could have a maximum value of 30. This score, therefore, not only measures the ability of a child to produce any quantity-comparative language, but also provides generally higher scores if the language used is correct, and potentially provides even higher scores if comparisons are made in more than one way. The maximum value of 30 could only be attained if a child produced more than one appropriate term to describe each of the ten tasks. The minimum score of 0 would result if no form of quantity-comparative language was elicited from the child in the entire productive language assessment. This score is referred to as the overall productive language score.
A second productive language score was determined for each child. This was designed to measure only the extended level of language production, defined in this study as a child's ability to produce quantity-comparative language in more than one way for a given comparison task. This score is referred to here as the extended productive language score, and is the column C total (productive language scoring sheet, Figure 1) for the child. While the overall productive language score includes information from columns A, B, and C, the extended productive language score ignores the first two columns. A child who produced only one appropriate term or phrase in each of the ten tasks would score 20 out of a possible overall productive score of 30, but would receive a 0 for his or her extended productive score. The extended productive language score could have values which ranged from 0 to 10. Table 1 provides a summary of the overall and the extended productive language scores.

Table 1

<table>
<thead>
<tr>
<th></th>
<th>Possible Range</th>
<th>Observed Range</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Score</td>
<td>0 - 30</td>
<td>0 - 29</td>
<td>16</td>
</tr>
<tr>
<td>Extended Score</td>
<td>0 - 10</td>
<td>0 - 9</td>
<td>2</td>
</tr>
</tbody>
</table>

No child achieved the maximum score of 30 in the overall productive language scoring; 29 was the highest score obtained. This was a substantial achievement for that child, in view of the design of the scoring method. Of the 97 children in the study, 11 children received a 0 for their overall productive language score, indicating a total absence of quantity-comparative...
language in their responses. The median score was 16, and a fairly even scoring spread was observed between the lowest (0) and highest (29) scores achieved. These results suggest that, to the extent that the children in this study may be considered representative, a large proportion of children do enter kindergarten able to recognize and to describe quantity comparisons.

However, the extended productive language scores indicate that many children were not able to describe quantity comparisons in more than one way: 37 of the children received a 0 extended productive language score, and the median score was 2. Children rarely described equal amounts in more than one way. When describing unequal amounts, it was expected that children would focus first on the larger amount and then on the smaller amount. Instead, they tended to describe the larger amount in two different ways. Also, despite the focusing attempts designed into the assessment, many children simply were not able, or chose not, to describe the smaller amount in an inequality situation.

Responsive Language

The responsive language assessment consisted of 11 different tasks. In each task, the subject responded to a conventional quantity-comparative term or phrase by selecting the one appropriate quantity card from three choice-cards presented (the fourth card displayed a reference quantity). Only one correct selection could be made in each task. The 11 phrases are listed in Table 2 in decreasing order of correct response; this order is not the same as the order of presentation of the tasks. The percentage of subjects who correctly responded to each phrase is also given in Table 2.
Table 2
Percentage of Subjects Responding Correctly to the Terms
Presented in the Responsive Language Assessment

<table>
<thead>
<tr>
<th>Term Assessed</th>
<th>Percentage of Subjects Responding Correctly</th>
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<tbody>
<tr>
<td>the same number as</td>
<td>98</td>
</tr>
<tr>
<td>is equal to</td>
<td>86</td>
</tr>
<tr>
<td>just as many as</td>
<td>86</td>
</tr>
<tr>
<td>a bigger number than</td>
<td>86</td>
</tr>
<tr>
<td>more than</td>
<td>82</td>
</tr>
<tr>
<td>a smaller number than</td>
<td>79</td>
</tr>
<tr>
<td>a greater number than</td>
<td>74</td>
</tr>
<tr>
<td>a larger number than</td>
<td>64</td>
</tr>
<tr>
<td>not as many as</td>
<td>59</td>
</tr>
<tr>
<td>fewer than</td>
<td>40</td>
</tr>
<tr>
<td>less than</td>
<td>27</td>
</tr>
</tbody>
</table>

Three of the 11 phrases used by the examiner referred to equal amounts, 4 to larger amount, and 4 to smaller amount. The most notable result of the responsive language assessment was that the children most frequently responded correctly to the equality terms. This is in sharp contrast to the productive language behavior of the children. While only two instances of the use of equal were observed in the productive assessment, 86% of the children responded correctly to equal in the responsive assessment. It appears from these results that, while children were better able to produce natural language which described inequality situations (especially referring to larger amount), they were better able to recognize and respond correctly to terms which described equality. Also, while children did appear to understand the term equal (responsive language), they avoided using it to describe equality situations (productive language), preferring instead the terms same or both have, which are less math-specific.
The second pattern which emerged from the responsive language assessment was that children were better able to respond correctly to terms which described the larger amount than to terms describing the smaller amount. The three terms to which children were least able to respond correctly referred to the smaller amount. Particularly notable was the fact that only 27% of the children responded correctly to less than, one of the most math-specific of the four terms used to refer to smaller amount.

When children responded incorrectly to an inequality task, they tended to select the card that was equivalent to the reference card. They responded to the inequality task as if it were an equality task. For example, the larger number than task employed a reference card which contained four objects and selection cards which contained two, four, and five objects. The correct selection for this task was the card with five objects. However, of the 34 children who made incorrect selections, 27 chose the card with four objects, the same number of objects as was on the reference card. The tendency to match the amount on the reference card when the child incorrectly responded to an inequality term, was also observed for the terms smaller than, more than, and bigger than. The only term for which this was not observed was less than: of the 69 children who made an incorrect choice, 46 chose the larger amount. This is a particularly interesting observation, as it relates to the "less is more" theory, described in Chapter II, that has been advanced by a number of researchers. The implications of this finding will be discussed in Chapter V.

A responsive language score was determined for each of the subjects, primarily, to enable the productive and responsive language analyses that are discussed in the next section of this chapter. The scores also permit an examination of the general level of the children's ability to respond to the
terms used in this assessment. The number of tasks in which a subject correctly responded to the term used by the examiner was taken as that subject's responsive language score. A child who responded correctly to all 11 terms, therefore, received a score of 11. Table 3 provides a summary of the responsive language scores.

Table 3
Summary of Responsive Language Assessment Scores

<table>
<thead>
<tr>
<th>Possible Range</th>
<th>Observed Range</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsive Lan-</td>
<td>0 - 11</td>
<td>3 - 11</td>
</tr>
<tr>
<td>guage Score</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In the responsive language assessment, all of the subjects were able to respond correctly to at least three of the tasks. The median number of tasks in which a correct response was given was 8, and 11 of the 97 children were able to respond correctly to all of the tasks. It may be concluded from these scores that children entering kindergarten generally do have a knowledge of quantity-comparative terms and are able to respond to them correctly. However, by themselves, the scores can be misleading. As has already been seen, the children's level of performance depended on whether the term referred to equality, to larger amount, or to smaller amount, and also depended on the degree of math-specificity of the term.

Relationships between Productive and Responsive Language Scores

The conclusions that have been drawn from the productive and responsive language assessments have referred primarily to the types of terms
children were able to produce, the children's facility in describing and responding to terms in various comparison categories, and the children's general levels of productive and responsive language abilities. In order to determine if there was a relationship between the productive and responsive language abilities of the subjects, Pearson product moment correlation coefficients were calculated for (a) overall productive language scores versus responsive language scores, and (b) extended productive language scores versus responsive language scores. The "extended" productive language score, described earlier, reflects the ability of a subject to produce, appropriately, more than one form of quantity-comparative language in a task.

The two resulting coefficients were then tested for rejection of the null hypothesis at an alpha level of .05. In each case, the null hypothesis was that the population correlation coefficient was zero; the research hypothesis was that the population correlation coefficient was non-zero. The results are summarized in Table 4.

<table>
<thead>
<tr>
<th>Type of Productive Language Score</th>
<th>r^a</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>.49*</td>
</tr>
<tr>
<td>B</td>
<td>.40*</td>
</tr>
</tbody>
</table>

*n = 97
* p < .01

Table 4

Relationship of Responsive Language Scores to (A) Overall Productive Language Scores, and (B) Extended Productive Language Scores

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Both hypotheses were rejected. It can be concluded, therefore, that responsive language scores are associated with overall productive language scores and also with extended productive language scores.

While positive relationships between productive language (overall and extended) and responsive language performance were found, neither relationship was strong. In particular, there was a wide variation of responsive language scores at the low end of both forms of productive language score. Children with a 0 overall productive score had responsive language scores which ranged from 3 to 10, and children with a 0 extended productive score had responsive scores ranging from 3 to the maximum score of 11.

The children's responsive language scores were generally higher than their productive language scores, yet it cannot be shown from the results of this study that responsive language precedes productive language development, or vice versa. However, the fact that a relationship exists between responsive and productive language suggests the need for a balance between the two modes of language in math instruction. This will be examined in more detail in the final chapter.

Productive and Responsive Language Scores of Subjects Grouped According to Background Attributes

The subjects were divided into two groups according to a background attribute, as described earlier. The analyses were based on grouping by sex, by race, and by the level of education of the child's mother. For each grouping, analyses of both productive and responsive language scores were performed. In each analysis, a $t$ statistic was calculated and was used to test the research hypothesis that the population means for the two groups were different, at an alpha level of .05.
In the following analyses, "productive language score" refers to the overall productive language score (range of values, 0 to 30). The extended productive language scores, which were calculated to enable an examination of children's abilities to describe comparisons in more than one way, were not relevant to this part of the study.

The first pair of analyses compared the productive and responsive language scores of boys with those of girls, and tested for significant difference between the mean language scores. At an alpha level of .05, the two-tailed t test on the mean scores was unable to reject the null hypothesis for either productive or responsive language. The research hypothesis, that the population mean score of boys differed from that of girls, was not supported in this study, for either the responsive or the productive language scores. While the sample means were slightly higher for girls than for boys in both language areas, the differences were not significant. The results of the tests are summarized in Table 5.

<table>
<thead>
<tr>
<th>Language Type</th>
<th>Variable</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Productive</td>
<td>Females</td>
<td>50</td>
<td>14.88</td>
<td>9.06</td>
<td>-.625</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>47</td>
<td>13.66</td>
<td>10.17</td>
<td></td>
</tr>
<tr>
<td>Responsive</td>
<td>Females</td>
<td>50</td>
<td>8.10</td>
<td>1.98</td>
<td>-1.358</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>47</td>
<td>7.47</td>
<td>2.58</td>
<td></td>
</tr>
</tbody>
</table>

In the second pair of analyses, the subjects were grouped by race and the mean scores of Caucasian children were compared with those of Black
children. The two-tailed t test could not reject the null hypothesis for productive language. The research hypothesis, that the population mean for Blacks was different from that of Caucasians, was not supported. In responsive language, however, the null hypothesis was rejected at the .05 level. Thus, the higher responsive language mean score for Caucasians (8.15 for Caucasians, 5.64 for Blacks) is significant. Table 6 provides a summary of the results.

Table 6
Productive and Responsive Language Scores of Subjects Grouped by Race

<table>
<thead>
<tr>
<th>Language Type</th>
<th>Variable</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productive</td>
<td>Caucasians</td>
<td>78</td>
<td>14.65</td>
<td>9.48</td>
<td>-.921</td>
</tr>
<tr>
<td></td>
<td>Blacks</td>
<td>14</td>
<td>12.07</td>
<td>10.70</td>
<td></td>
</tr>
<tr>
<td>Responsive</td>
<td>Caucasians</td>
<td>78</td>
<td>8.15</td>
<td>2.13</td>
<td>-4.056*</td>
</tr>
<tr>
<td></td>
<td>Blacks</td>
<td>14</td>
<td>5.64</td>
<td>2.13</td>
<td></td>
</tr>
</tbody>
</table>

*p < .001

During the administration of the responsive language assessment, it was observed that many of the Black children appeared to have difficulty responding to the standard quantity-comparative terms that were presented. The results of the t test support this observation. However, as discussed in Chapter III, the probabilities of type I and type II errors in the t test may not be what are normally expected when the sample sizes are unequal. Because of the possibility of misinterpreting the t test results, a second analysis was performed (using a Mann-Whitney U test) to corroborate the findings of the t test.
For sample sizes larger than 20, the sampling distribution of the Mann-Whitney $U$ approaches the normal distribution, and the related $z$ statistic is used instead of $U$ in the significance test (S. Siegel, 1956, p. 120). This is a one-tailed, directional test, and an alpha level of .025 was selected (half the level used in the preceding non-directional $t$ test). Both productive and responsive language scores were tested. In each test, the null hypothesis was that there was no difference between the language scores of Blacks and Caucasians. The research hypothesis was that the language scores of Caucasians were higher than those of Blacks. The direction of the research hypothesis was selected on the basis of the higher mean language score for Caucasians (presented in Table 6). The results of the Mann-Whitney test are summarized in Table 7.

<table>
<thead>
<tr>
<th>Table 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mann-Whitney Test of Productive and Responsive Language Scores of Subjects Grouped by Race</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Language Type</th>
<th>Variable</th>
<th>$n$</th>
<th>$U$</th>
<th>$z$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productive</td>
<td>Blacks</td>
<td>14</td>
<td>622</td>
<td>.826</td>
</tr>
<tr>
<td></td>
<td>Caucasians</td>
<td>78</td>
<td>470</td>
<td></td>
</tr>
<tr>
<td>Responsive</td>
<td>Blacks</td>
<td>14</td>
<td>850</td>
<td>3.304*</td>
</tr>
<tr>
<td></td>
<td>Caucasians</td>
<td>78</td>
<td>242</td>
<td></td>
</tr>
</tbody>
</table>

*$p < .001$

For productive language, the Mann-Whitney test was unable to reject the null hypothesis. No difference in the productive language scores of Blacks and Caucasians could be shown. For responsive language, however, the null hypothesis was rejected (alpha level = .025). The direction of rejection of $H_0$ was toward acceptance of $H_1$; this is confirmed by examining the associated
U values (U = 850 for Blacks, U = 242 for Caucasians). A higher U value indicates a lower ranking (S. Siegel, 1956). The research hypothesis, that the responsive language scores of Caucasians were higher than those of Blacks, was accepted.

The Mann-Whitney test, therefore, supported the results of the t test. Chapter V will examine the implications of the finding that a difference between Blacks and Caucasians was shown in responsive language performance but not in productive language performance.

In the final analysis of productive and responsive language scoring (summarized in Table 8), children were grouped according to the educational level of their mothers. Children in one group were those whose mothers had received an associate's degree or a higher degree. The mothers of children in the second group had received a high school diploma or less education. The latter group included cases where some post-secondary education had been received, but no degree beyond the high school diploma had been obtained.

Table 8

<table>
<thead>
<tr>
<th>Language Type</th>
<th>Variable</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productive</td>
<td>Lower</td>
<td>62</td>
<td>12.84</td>
<td>9.59</td>
<td>2.270*</td>
</tr>
<tr>
<td></td>
<td>Higher</td>
<td>34</td>
<td>17.35</td>
<td>8.79</td>
<td></td>
</tr>
<tr>
<td>Responsive</td>
<td>Lower</td>
<td>62</td>
<td>7.07</td>
<td>2.24</td>
<td>5.139**</td>
</tr>
<tr>
<td></td>
<td>Higher</td>
<td>34</td>
<td>9.27</td>
<td>1.48</td>
<td></td>
</tr>
</tbody>
</table>

The lower educational level includes subjects whose mothers were educated up to, but not including, receipt of an associate's degree. Higher educational level refers to maternal education at and above the associate's degree level.

*P < .05
**P < .001
A t test was applied to the mean scores of the two groups, for both productive and responsive language. The null hypothesis, that there was no difference in the population means of children in the lower and higher maternal education categories, was rejected (alpha level = .05) for both productive language and responsive language. The higher mean score for children with more highly-educated mothers was significant in both language areas.

To summarize the demographic results, when the children's productive and responsive language scores were examined with the children grouped by sex, by race, and by maternal educational level, the following results were obtained. A difference in the quantity-comparative language scores of boys and girls could not be shown, in either productive or responsive language. Similarly, no difference could be shown in the productive language abilities of Black children and Caucasian children. However, the higher mean responsive language score of Caucasian children was found to be significant. When children were grouped according to maternal educational level, a higher mean score for children with more highly-educated mothers was found to be significant, for both productive and responsive language.

Comparison of Children's Productive and Responsive Language with the Language of Typical Kindergarten Math Programs

Kindergarten mathematics programs are usually based on a math textbook series used in the elementary grades. Regardless of whether a workbook is used in kindergarten, the teacher's guide for the particular series used in the school system tends to be the basis for math instruction in kindergarten.

Seven major mathematics series published since 1975 were examined for quantity-comparative vocabulary content at the kindergarten and first-grade
levels. The differences among the seven series were considerable. Two of the series did not include any form of vocabulary or keyword list in the teacher's editions, at either the kindergarten or the first-grade level. Four of the series did include a list of vocabulary in the chapter introduction sections of the teacher's editions. Only one series included a vocabulary list for each lesson in the kindergarten and first-grade teacher's editions.

None of the series alerted teachers to language implications in a discussion of the lesson format. In fact, although some language terms were identified in the vocabulary lists, this language was restricted to specific math terminology. Vocabulary lists seldom included normal usage words or those words identified by Monro (1979) as being most confusing to children because of their dual meaning (in everyday language and in mathematics language). No suggestions were made about the use of the vocabulary list, when a list was provided, nor were suggestions given for the words a teacher might use (or avoid using) when teaching a particular concept.

The vocabulary and level of introduction varied greatly among the seven series that were examined. Table 9 presents the terms that were compiled from the kindergarten and first-grade levels of the seven series, regardless of the number of series that actually presented each term. (Appendix D indicates the number of series that used each term at the kindergarten level and at the first-grade level.) Beside each term in Table 9 is the number of instances in which that term was used by the children of this study to describe a quantity comparison (productive language).

Twelve of the terms in Table 9 were also produced by children in this study. However, 11 of the terms were not used at all by the children, and there were many other terms that the children produced which did not appear
Table 9
Comparison of the Children's Productive Language with the Vocabulary of the Textbook Series

<table>
<thead>
<tr>
<th>Textbook Vocabulary</th>
<th>Number of Times the Children Used the Term in the Productive Language Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>more</td>
<td>260</td>
</tr>
<tr>
<td>same number</td>
<td>98</td>
</tr>
<tr>
<td>less, lesser, least</td>
<td>37</td>
</tr>
<tr>
<td>most</td>
<td>31</td>
</tr>
<tr>
<td>as many as</td>
<td>15a</td>
</tr>
<tr>
<td>some</td>
<td>11</td>
</tr>
<tr>
<td>different</td>
<td>11</td>
</tr>
<tr>
<td>many</td>
<td>11</td>
</tr>
<tr>
<td>smaller, smallest</td>
<td>8</td>
</tr>
<tr>
<td>few, fewer, fewest</td>
<td>5</td>
</tr>
<tr>
<td>equal</td>
<td>2</td>
</tr>
<tr>
<td>match</td>
<td>1</td>
</tr>
<tr>
<td>larger, largest</td>
<td>0</td>
</tr>
<tr>
<td>all</td>
<td>0</td>
</tr>
<tr>
<td>one more than</td>
<td>0</td>
</tr>
<tr>
<td>one fewer</td>
<td>0</td>
</tr>
<tr>
<td>not any</td>
<td>0</td>
</tr>
<tr>
<td>alike</td>
<td>0</td>
</tr>
<tr>
<td>pair</td>
<td>0</td>
</tr>
<tr>
<td>greater</td>
<td>0</td>
</tr>
<tr>
<td>difference</td>
<td>0</td>
</tr>
<tr>
<td>one less than</td>
<td>0</td>
</tr>
<tr>
<td>one greater than</td>
<td>0</td>
</tr>
</tbody>
</table>

*count includes not as many as*

in the textbooks. It is evident from this comparison that, while many children entering kindergarten have the ability to describe quantity comparisons in their own language, there is only a partial match between the children's language and the vocabulary of the textbooks. Many of the terms used in the textbooks do not appear to be part of the natural language of the children.

The seven textbooks were also examined for inclusion of the terms that were presented in the responsive language assessment. Table 10 lists the 11
terms that were used in the responsive language assessment, the percentage of children who responded correctly to each term, and the number of textbook series that introduced the term at the kindergarten and first-grade levels.

Table 10

Comparison of the Number of Textbook Series Using the Terms of the Responsive Language Assessment with the Children's Abilities to Respond Correctly to the Terms

<table>
<thead>
<tr>
<th>Term Assessed</th>
<th>Percent Correct Response</th>
<th>Number of Textbook Series Using the Term</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>in Kindergarten</td>
</tr>
<tr>
<td>same number</td>
<td>98</td>
<td>7</td>
</tr>
<tr>
<td>equal</td>
<td>86</td>
<td>1</td>
</tr>
<tr>
<td>just as many as</td>
<td>86</td>
<td>6</td>
</tr>
<tr>
<td>bigger (number)</td>
<td>86</td>
<td>7</td>
</tr>
<tr>
<td>more than</td>
<td>82</td>
<td>7</td>
</tr>
<tr>
<td>smaller (number)</td>
<td>79</td>
<td>7</td>
</tr>
<tr>
<td>greater number</td>
<td>74</td>
<td>2</td>
</tr>
<tr>
<td>larger (number)</td>
<td>64</td>
<td>7</td>
</tr>
<tr>
<td>not as many as</td>
<td>59</td>
<td>0</td>
</tr>
<tr>
<td>fewer than</td>
<td>40</td>
<td>3</td>
</tr>
<tr>
<td>less than</td>
<td>27</td>
<td>4</td>
</tr>
</tbody>
</table>

a seven textbook series were examined

Although 86% of the children in this study responded correctly to equal, only one of the seven series used that term in kindergarten. It should also be noted that the series which were examined did not necessarily associate the terms smaller, bigger, and larger, with amount or number. While those terms were included in all seven series, they may have been used to refer to size, and not to quantity.

All seven series introduced either less or fewer at the kindergarten level, yet the children of this study had the most difficulty with these two terms.
The children appeared to have much greater familiarity with the term smaller number in referring to a smaller amount. Also, a rather surprising 74% of the children in this study demonstrated an understanding of the term greater (10% more children than correctly responded to larger number), however only two textbook series used this term in the kindergarten program. These observations are discussed further in the following chapter, in conjunction with curriculum recommendations suggested by the findings of this study.

This chapter has reported the results of the productive and responsive language assessments and the results of analyses of the data derived from those assessments. It has also compared the language performance of the children in this study with the quantity-comparative terms used in typical kindergarten math programs. The next chapter presents interpretations of the findings. It examines what has been shown about the quantity-comparative language abilities of young children and how these findings relate to previous research. Chapter V also discusses the results from the point of view of implications for kindergarten curricula, and presents recommendations for further research.
CHAPTER V
DISCUSSION, RECOMMENDATIONS, AND CONCLUSIONS

This chapter consists of three sections. The first section examines the study results and presents interpretations of the findings. The next section is a summary of the investigation — the goals of the study, related research, the study design, and the results. The concluding section then presents recommendations that have been suggested by the findings of this study.

Interpretation of the Findings

This study was undertaken to provide information about the abilities of young children to produce and to understand quantity-comparative descriptions. Data were collected by means of a productive language assessment (to elicit, in the child's own language, descriptions of quantity comparisons), and a responsive language assessment (to examine the child's ability to respond correctly to conventional quantity-comparative terms).

In the productive language assessment, the children produced 76 different terms or phrases to describe the comparison situations. These are listed in Appendix C. The term more was by far the most popular of all the terms produced by the children. However, this preference must be interpreted with caution, since more was not necessarily always used to identify a larger amount. This is an important point, considering that more than was not the term to which most children responded correctly in the responsive language assessment. Although 82% of the children did respond correctly to more than, four other terms received higher percentages of correct response. In other
words, while children may often use the term more, it may not always have a quantitative meaning for them. This point has also been raised in previous studies, such as those of Brush (1976), and of Grieve and Dow (1981). It is possible that some children, when saying, "more," were referring to something unrelated to quantity, such as the spatial arrangement of the objects, for example.

L. Siegel (1977) found that, in working with unequal amounts, young children are more likely to describe the larger amount than the smaller. The present investigation provides additional evidence of children's preference for the larger amount. Not only was it evident in the higher number of instances of referral to larger amount, but it was also observed in the extended language production behavior of the children. The main reason for calculating an extended productive language score was to determine the extent to which children were able to make quantity comparisons in more than one way. It was expected that the extended productive language score would identify the proportion of children who could describe both larger and smaller amounts when faced with unequal quantities. However, many children either were unable, or chose not, to change the focus of their description, and simply produced a second description of the larger amount.

The relative difficulty with which children described equality situations supports the findings of LaPointe and O'Donnell (1974) which indicated that tasks involving more were easier than those of equivalence. Griffiths et al. (1967) also observed that children described an equality significantly less often than an inequality. The current study found that, not only was the frequency of production of equality terms lower than was expected, but also that during the productive language assessments, high-scoring children were almost always
prevented from obtaining the maximum score of 30 by their inability to
describe an equality in more than one way. The fact that equal was only used
twice by the 97 children (even though the responsive language results indicated
that the term was well-understood), suggests that children are not nearly as
comfortable with the use of the term as they are with the less math-specific
term, same.

It has already been noted that, in the productive language assessment,
many of the phrases that referred to smaller amount were the negative forms
of terms referring to larger amounts, for example, not more than. While this
is another example of the children's preference for terms which refer to the
larger amount, it also raises an interesting point. Not more than was accepted
by the examiner as a phrase which the child was using to describe the smaller
amount. However, not more than and less than are not synonymous. Not more
than means less than or equal to. This is not likely to cause problems for
children at the kindergarten level, but at some point an understanding that the
two terms are not synonymous will become necessary.

Another difference in the terms produced to describe larger, smaller,
and equal amounts was the frequent use of numbers in the descriptions of
equal and smaller amounts, but not in those of larger amounts. One
interpretation of this observation is that children may feel comfortable with
the terms they have at their disposal to describe the larger amount, and
therefore don't need to refer to the numbers involved in the comparisons. A
related observation was that some children counted the number of objects
before describing the comparison, while others stated the number of objects
without having counted. It appeared that children who counted (accurately or
not) tended to describe the comparison in terms of numerical values and,
frequently, either were unable, or chose not, to use quantity-comparative language for that task. The strategies children use in situations where they are required to produce quantity-comparative language should be given further study, since the strategy chosen by the child did appear to influence the child's productive language performance.

The results of the responsive language assessment indicated that the children were better able to recognize and to respond to conventional terms of equality than they were to conventional terms of inequality. Of the three comparison categories, the children were least able to respond correctly to terms which referred to smaller amount. This finding is consistent with studies (Donaldson & Balfour, 1968; Palermo, 1973, 1974) which claimed that children's understanding of more develops prior to their understanding of less, and appears to support the findings of Sarro (1980) that both more and same are understood prior to less.

Eight of the 11 responsive language tasks assessed terms which described inequality. It was noted that in four of those tasks, when children made an incorrect selection, they tended to pick a quantity which was equal to the reference quantity. The format of three of the remaining four inequality tasks did not permit further observation of this behavior (in two of the tasks, an amount equal to the reference card was not presented; in the third task, both possibilities for incorrect choice were equal to the reference amount).

The tendency to err in favor of an equal amount is an observation that should receive further study. However, the examination of that tendency will require an assessment designed specifically with that purpose in mind; the responsive language assessment of this study used randomly-generated quantities which, as has been mentioned, precluded additional observation of the tendency in three tasks.
The one inequality task in which this tendency could have been observed, but was not, was the less than task. Forty-six of the 69 incorrect respondents focused on the larger amount. A number of researchers (E. Clark, 1973; H. Clark, 1970; Donaldson & Balfour, 1968; Donaldson & Wales, 1970) have stated that young children use the term less synonymously with more (the "less is more" theory). While the current study did not set out specifically to examine their claim, it appears that the results do provide some support for the theory.

In considering children's performance in the responsive language assessment, two other observations may be made. It is possible that errors in response to not as many as were due to the negative form of the phrase. Some children may not have heard the negation. Children's responses to not as many as may also have been influenced by the assessment format. Because this was the only negative phrase used in the responsive language assessment, the structure of the questioning may have been more difficult to understand than in the other ten tasks. It also should be noted that more children responded correctly to the term smaller than than to any of the other terms used to describe a smaller amount. In view of the children's apparent weaknesses in responding to terms referring to smaller amount, consideration should be given to the use of smaller than in developing an understanding of the more difficult terms, less and fewer.

To summarize the conclusions drawn from the productive and responsive language assessments, it appears that a large proportion of children do enter kindergarten able to recognize and to describe quantity comparisons in their own language. They also appear, in general, to be able to respond correctly to many conventional quantity-comparative terms. However, it has also been shown that there are varying levels of facility with which children are able to
use and to respond to the terms. The determining factors appeared to be the degree of math-specificity of the term and the nature of the comparison being made. These findings provide a clear indication of the need to consider language development as an integral part of mathematics instruction.

The analysis of the relationship between children's responsive and productive language scores indicated a positive correlation. This study was not designed to show a causative link between productive and responsive language, nor could it show that one precedes the other. However, the fact that a relationship does exist indicates a need to emphasize (a) a language-development approach to the introduction of quantity-related words prior to math instruction which involves this language, in conjunction with (b) a learning environment which encourages young children to talk about quantity comparisons as a means of developing an understanding of the language and the concepts involved. This need has also been recognized by Farnham (1975), who stated that math instruction should involve a balance between the two modes of language.

The productive and responsive language scores were analyzed with the children grouped by sex, by race, and by maternal educational level, to determine if relationships could be found between the grouping characteristic and the language scores. The study was not able to show a difference in the productive or responsive language abilities of boys and girls. Martin's (1951) findings, that boys outperformed girls on tasks requiring the production of quantity-related words, were not supported in the current investigation. However, the results do support the findings of Fennema (1974), Ginsburg and Russell (1981), and Stanley et al. (1974), which indicated that boys and girls begin school with approximately equal aptitude and abilities for learning mathematics.
When the children were grouped according to the level of education of their mothers, a higher mean language score (in both productive and responsive language) for children with more highly-educated mothers was found to be significant. These results appear to support the findings of several researchers (Cross, 1977; Olim, 1970; Schachter, 1979; Tough, 1977), which indicated that maternal language styles and socioeconomic status greatly affect children's language development.

It should be noted that the results obtained in this study do not refute theories (Ginsburg, 1972; Labov, 1970; Rosen, 1972) which claim that lower socioeconomic language can deal adequately with logical and abstract thinking. However, the findings do suggest the need to emphasize quantity-comparative language development in young children to ensure that all children begin their formal instruction in mathematics with an understanding of the words being used.

The fact that a difference was found between the two maternal education groups is not unreasonable when one considers Schachter's (1979) view that, of all socioeconomic factors, maternal education may have the greatest impact on the child's development, by virtue of its association with access to adequate child development information. In addition, there may be a relationship between the mother's educational level and her level and type of employment. This, in turn, may affect the nature of the child's environment and the amount of time the mother has to spend with her child, as well as the type of child care she is able to provide for the child in her absence. All these factors can play an important role in the young child's developing language skills.
When children were grouped by race, no difference in productive language scores could be shown between Black children and Caucasian children. However, a significant difference in the responsive language scores was found; the Caucasian children scored higher in that assessment. The fact that many Black children were able to describe quantity comparisons (productive assessment) yet had difficulty responding to the terms of the responsive language assessment, suggests that the conventional terms assessed may not have been as familiar to the Black children as they were to the Caucasian children.

Farnham's (1975) proposal, that children's "folk" language ought to play an important role in the development of math understanding, should be given serious consideration if, in fact, young children are coming to kindergarten with language which is not commensurate with the language of instruction. It is also appropriate to consider the recommendations of Novillis (1979), Preston (1978), and Pollak and Gruenewald (1978), which emphasize an organized and consistent approach to math instruction for young children that includes a match between the child's language and the language of math instruction. This approach can ensure equal opportunity for all children to develop an understanding of math concepts.

It is important to avoid overgeneralization of findings which show differences between groups of children. Such inferences can lead to prejudgment of a child's abilities based solely on his or her background characteristics. It is not always possible to know if the observed differences are, in fact, due to the child's ability. For example, Labov (1970) has contended that many assessment procedures inhibit the production of language and that misinterpreted dialect differences result in lower scores for minority children.
The fact that Black children's scores in the language production assessment of this study were comparable to those of Caucasian children, and that the difference between the groups was observed in the responsive assessment (in which the child was not required to speak), indicate that Labov's concerns may not be applicable to this study. However, it is possible that dialectal differences between the investigator and the minority child may have had some influence on responsive language scores. Whether due to genuine or extraneous factors, the group differences that have been observed in this study indicate the need for particular attention to be given to children whose culture or environment may produce language forms different from those used in mathematics instruction.

In an analysis of the vocabulary of three primary arithmetic series, Horodezky and Weinstein (1981) found a great variation between the series in the number of different terms used. They concluded that their data suggest a possible problem in vocabulary usage in primary arithmetic series. They also noted that terms were seldom repeated throughout a particular book and that there was a low degree of vocabulary overlap between successive books of a particular series. They felt that the lack of word repetition and vocabulary control might present a problem to young children learning mathematics. In a review of eight kindergarten math programs, Yvon and Spooner (1982) also noted that the concepts presented in the different programs varied greatly (of 106 concepts identified, only 29 were presented in a majority of the programs).

The findings of these two studies are consistent with the observations of this investigation. Considerable vocabulary-related differences were noted among the seven math series examined. None of the series cautioned teachers about the importance of language to the development of math concepts, and
no suggestions were made about the use of the vocabulary list, when a list was provided.

Vocabulary lists in math textbooks should not be interpreted as being complete descriptions of all the math-related words to which a child may be exposed. Although a term may not be included in a vocabulary list, or the lesson objective, or the teaching strategy, its use may be implied by the instructional format suggested for the lesson. It is probably safe to assume that most, if not all, of the terms used in this study's responsive language assessment are also used by kindergarten and first-grade teachers. The use of certain of the terms might be implied by the textbook's teacher's guide. Or, because the terms are commonly used in adult language, the teacher might use the words instinctively in developing math concepts with children.

Since the findings of this study indicated that children seem to comprehend the term smaller number better than the terms fewer or less, consideration should be given to using the term smaller in math instruction, with particular reference to quantity. All seven series introduced either less or fewer at the kindergarten level. Therefore, despite the fact that the children of this study had the most difficulty with these two terms, they will probably be encountering one or the other of the terms in kindergarten mathematics.

Horodezky and Weinstein (1981) have found that teachers tend to rely mainly upon textbooks for guidance in the instruction of mathematics. Accordingly, there appears to be an immediate need to provide teachers with more adequate information about language implications in the learning of mathematics. Instructional strategies should be suggested which:

(a) alert teachers to children's levels of understanding of quantity-comparative vocabulary,
(b) begin math concept development with language that is familiar to the children, and

(c) through a systematic process of language instruction, help children to use and to understand the specific quantity-comparative language of mathematics.

There is also a need to improve the quality of the instructional material that is being published, to ensure that it addresses both the logical and the psychological aspects of the learning of mathematics.

Summary of the Study

While it is generally acknowledged that language plays a role in the development of math skills in young children, the nature of that role is not clear. Language that deals with quantity comparisons (such as equal, less, and more) can have specific meaning when used in math instruction; yet the terms, or the usage of the terms, may not be familiar to the child. Conversely, the natural language used by a child to describe those concepts may not be the same as the language used in math instruction. Because of the importance of language to the development and measurement of understanding of math concepts, the purpose of this study was to examine young children's production and understanding of quantity-comparative language, in order to provide a description of the language abilities of children who are about to enter kindergarten. It was expected that this information not only would help to clarify some of the findings of related research, but also could be used in a comparison with the language of kindergarten math programs. Within the context of that purpose, the study goals were (a) to measure and to describe the language produced by young children in making quantity comparisons (productive language), (b) to examine children's abilities to respond to conventional quantity-comparative terms (responsive language), (c) to study the
association between productive and responsive language, (d) to examine the children's productive and responsive language abilities for differences based on demographic factors, and (e) to compare the children's understanding and production of quantity-comparative terms with the terms used in typical kindergarten math textbook series.

The investigation of the problem involved a review of the literature in three areas: cognitive development research, linguistics research, and math education research. The findings presented in the literature were often ambiguous, occasionally contradictory, and generally inconclusive. The principal difficulty was the involvement of three separate disciplines and the absence of a clear synthesis of the many different theories and research findings. One conclusion that could be drawn from the literature was the existence of a strong, but undefined, interplay between language development and mathematics development. Another was the need for research directed toward the delineation of the linguistic and cognitive abilities of preschool-aged children.

The subjects were selected for the study by means of a stratified random sampling of children who were attending early childhood facilities in the Kalamazoo area. The children ranged in age from 4 years, 9 months, to 5 years, 3 months, on April 1, 1982. Ninety-seven children participated in the study.

During the Spring of 1982, each child was interviewed by the investigator. The interview consisted of an introductory activity, a productive language assessment, and a responsive language assessment. The productive language assessment was designed to elicit from the subject, in his or her own language, descriptions of quantity comparisons. The responsive language
assessment was designed to examine the ability of the subject to respond correctly to quantity-comparative terms presented by the examiner.

The results of the two assessments indicated that many children do have the ability to describe quantity comparisons and also to respond correctly to the conventional terms that were assessed. However, a number of factors were observed which suggested that children have varying levels of facility in producing, and responding to, quantity-comparative language. The degree of math-specificity of the term and the direction of the comparison appeared to influence the children's levels of language ability.

Scores were determined for each child's responsive and productive language. An analysis of those scores indicated a positive correlation between overall productive language ability and responsive language ability. The ability of a child to produce more than one appropriate description of a quantity comparison was also found to be related to responsive language ability.

Mean productive and responsive language scores were tested to determine if differences could be shown which were based on sex, race, or the level of education of the child's mother. The two-tailed t test of the mean language scores of children grouped by sex was unable to show a difference in scores of boys and of girls, in either productive language or responsive language. Similarly, no difference could be shown in the productive language scores of Blacks and Caucasians. However, both the t test and a Mann-Whitney U test indicated significantly higher responsive language scores for Caucasian children. When the children were grouped according to maternal educational level, children of more highly-educated mothers had significantly higher scores in both productive and responsive language.
An examination of the vocabulary content of seven textbook series at the kindergarten and first-grade levels indicated considerable variation between the series in the number of different terms used and the level at which the terms were introduced. When the textbook vocabularies were compared with the quantity-comparative language produced by the children of this study, only a partial match between the two was found. Many of the textbook terms did not appear to be part of the natural language of the children. Similar discrepancies were noted in a comparison of the number of textbooks which included the terms of the responsive language assessment with the children's abilities to respond correctly to the terms. Math textbooks often define the curriculum for kindergarten math instruction, and teachers tend to rely heavily upon the textbook for direction in math instruction. Considering the findings of the present study, it seems imperative that teachers are provided with information about the implications of language in the learning of mathematics.

Recommendations and Conclusions

This study has produced a number of findings which provide a clearer picture of the quantity-comparative language abilities of young children and which have enabled a comparison of those abilities with the language used in typical kindergarten math programs. In a study such as this, which is basically descriptive in nature, there can be a danger in attempting to interpret the results too broadly. However, a number of observations were made that suggest a need for further, more detailed investigation. The recommendations are presented in the following order: recommendations which stem from limitations of the study, recommendations for future research, and recommendations which pertain to curriculum.
There are two factors which need to be considered when selecting subjects in future research of this type. First, the results obtained from a study could be more broadly interpreted if a random sample of children were drawn from all the children who are entering kindergarten within a given area. The method of identification of subjects for this study excluded from consideration children who did not attend some form of early childhood facility. Second, sampling techniques should be designed to ensure greater representation of minority children if any racial influences are to be studied in the investigation. While this study employed a proportional stratified sampling technique to obtain adequate representation of children from each of the three types of early childhood facilities, the random sample contained a disproportionately low number of minority children.

Because very few studies have directly examined the young child's use and understanding of quantity-comparative language, it was not possible to use established instruments for these assessments. The techniques used in the study were extracted from somewhat relevant studies, were modified on the basis of pertinent research findings, and were revised according to the results of the pilot tests. An independent observer and judge were used to establish objectivity and reliability of scoring and coding, while validity was indicated by the results of the pilot studies and by the use of similar techniques in previous studies. However, it is recognized that the validity and reliability of the procedures used in this study have not been firmly established. It is recommended that future investigations devise statistically reliable and valid measures for assessing productive and responsive language abilities.

The observation made during the responsive language assessment, that children who responded incorrectly to inequality terms tended to choose the
equal amount, is recommended for further study. The assessment procedure will require tasks which are designed specifically to evaluate that tendency. As was mentioned earlier, the randomly-generated quantities used in this study, in some cases, prevented further observation of that tendency.

The examination of the relationship between responsive and productive language scores indicated a positive correlation. However, the nature of the relationship could not be examined, beyond that finding, by the methods used in this study. Further investigation of this relationship is recommended, using experimental design techniques, to see if it can be shown whether language production abilities or responsive language abilities develop earlier in children.

This study has focused on children's use and understanding of quantity-comparative language. However, the relationship of language to the development of math concepts, a much broader issue, has not been dealt with here. There is a need for information gathered through longitudinal investigations, to examine the nature of the interaction between language skills and math learning.

During the administration of the productive language assessment, children appeared to have strategies for making quantity comparisons. This was an interesting observation that merits further attention, as the children's performance appeared to be related in some fashion to the strategy used. Specifically, it would be useful to determine (a) if counting helps or hinders the production of quantity comparisons, (b) if there is a relationship between the failure to count accurately, when a counting strategy is used, and the inability to produce appropriate comparative language, and (c) if the ability to subitize (to name spontaneously a number of objects without having counted the objects) is related to productive language performance, and if so, is it a more effective strategy than counting?
Perhaps the most important implications that may be drawn from this study are those of a more practical nature, those that have been derived from the demographic analyses and from the comparison of the children's language abilities with the language used in kindergarten curricula. These findings tend to have more immediate application to the teaching of mathematics. For example, the analysis of group scores indicated that the stereotypical views of the relative abilities of girls and boys, or Blacks and Caucasians, may be unfounded. There are many such views: that boys have better potential in math, that girls' language skills are superior, and that the language of minority children is deficient. These views, which can become self-fulfilling, may have no basis in fact. However, because the language of math instruction may not be equally familiar to all groups of children, for a variety of extraneous reasons, language development must be a precursor to concept development in mathematics. Otherwise, it may be language that deprives children of the opportunity to develop their full potential in math.

The wide variation found in the seven kindergarten math programs suggests the need for a comprehensive evaluation of current math textbooks. From the examination made in this study, it was apparent that insufficient emphasis is being placed on the matching of the vocabulary of the math programs with the actual language abilities of the children. The most effective way to correct this deficiency and, at the same time, to incorporate the other curricular recommendations of this study, is the adoption of the three-fold approach mentioned earlier. An instructional strategy should be developed which, first, alerts teachers to children's levels of understanding of quantity-comparative vocabulary, second, begins math concept development with language that is familiar to the children, and third, helps children to use
and to understand the specific quantity-comparative language of mathematics, through a systematic process of language instruction.

In conclusion, the results of this investigation appear to have addressed, at least in part, the concern of Gelman (1978), that studies in this area have tended to provide a better description of what children are not able to do than an indication of their actual abilities. It is hoped that the issues raised by this study have illustrated the need for additional research which can lead to a better understanding of children's abilities. It is also hoped that the findings of this study will encourage teachers, curriculum leaders, and publishers to appreciate the importance of language in the development of math concepts.
April 5, 1982

Dear Mr. and Mrs. Smith:

Your child, John, has been chosen to participate in a study about young children and mathematics. The study is being conducted by Sandra Howe in cooperation with Western Michigan University.

The study activities will be presented as a game in a pleasant atmosphere. They will last approximately 15 minutes and will take place in private at your child's school. The activities are very similar to those taking place in your child's classroom. At no time will your child be led to think that there is a "right" answer. We expect each child to have a pleasant and successful experience.

Responses will be held in strictest confidence. Neither teachers nor administrators will see your child's answers, and your child's name will never appear in connection with the resulting information.

We expect that the information gained from this study will be useful in planning meaningful kindergarten mathematics experiences. If you are willing to aid in this educational study by allowing your child to take part, please respond to the questions, and sign and return the form below. Your child will not be asked to participate unless your return the completed form.

If you have any questions please call your child's teacher, or Sandra Howe at 791-8110.

Thank you,

----------------------------------------
Yes, I give my permission for John Smith to participate in the activities described above.

Your Signature: __________________________ Date: ___________

Will your child be attending kindergarten in Fall, 1982? __yes __no

Your child's birthdate: ___ Month ___ Day ___ Year

Describe the education of the child's mother. (Check one)
   ___ Grade school education
   ___ Attended high school but did not finish
   ___ Graduated from high school
   ___ Attended college but did not receive a degree
   ___ Associate's degree
   ___ Bachelor's degree
   ___ Master's degree or higher

PLEASE RETURN THIS FORM TO YOUR CHILD'S SCHOOL

(SH/0199)
APPENDIX B

Observation Sheet

<table>
<thead>
<tr>
<th>Observation Sheet</th>
<th>Child</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tape #</td>
<td>start stop</td>
</tr>
<tr>
<td>Sex</td>
<td>Race</td>
</tr>
</tbody>
</table>

Pre-Assessment Activity - amounts 4, 2

Productive Assessment - "This is this bear's plate, and that is that bear's plate. [blocks]
- "What can you tell me about these two groups of blocks?"
- "Tell me what you see." "What else?" "Can you tell me another way?" [how do you think this bear likes his blocks? Why?]

| 1 3, 4 | : : : |
| 2 2 | : : |
| 5, 2 | : : |
| 3, 3 | : : |
| 2, 3 | : : |
| 5, 5 | : : : |
| 2, 4 | : : |
| 3, 2 | : : |
| 2, 5 | : : |
| 4, 3 | : : |

Responsive Assessment - "Here is a card and here are some others, look at this card, now find a card that has ------ this one."

1. just as many as 3 - 3 2 5
2. less than 4 - 5 3 4
3. not as many as 3 - 3 2 3
4. a greater number than 4 - 3 3 2
5. more than 3 - 4 2 3
6. is equal to 5 - 2 3 5
7. the same number as 2 - 2 4 3
8. a larger number than 4 - 2 4 5
9. a bigger number than 3 - 3 3 2
10. a smaller number than 4 - 4 2 5
11. fewer than 3 - 3 5 4
APPENDIX C

Productive Language Frequency Lists

Children's Descriptions of a Larger Amount

<table>
<thead>
<tr>
<th>Description</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>more</td>
<td>260</td>
</tr>
<tr>
<td>a lot (lots)</td>
<td>38</td>
</tr>
<tr>
<td>most</td>
<td>27</td>
</tr>
<tr>
<td>a lot more</td>
<td>12</td>
</tr>
<tr>
<td>enough</td>
<td>9</td>
</tr>
<tr>
<td>mostest</td>
<td>8</td>
</tr>
<tr>
<td>more bigger</td>
<td>7</td>
</tr>
<tr>
<td>bigger</td>
<td>7</td>
</tr>
<tr>
<td>many</td>
<td>6</td>
</tr>
<tr>
<td>too much</td>
<td>3</td>
</tr>
<tr>
<td>too many</td>
<td>3</td>
</tr>
<tr>
<td>a whole lot</td>
<td>3</td>
</tr>
<tr>
<td>morest</td>
<td>2</td>
</tr>
<tr>
<td>biggest</td>
<td>2</td>
</tr>
<tr>
<td>a little more</td>
<td>2</td>
</tr>
<tr>
<td>big</td>
<td>1</td>
</tr>
<tr>
<td>way more</td>
<td>1</td>
</tr>
<tr>
<td>that many</td>
<td>1</td>
</tr>
<tr>
<td>bigger number</td>
<td>1</td>
</tr>
<tr>
<td>many-er</td>
<td>1</td>
</tr>
<tr>
<td>more lots</td>
<td>1</td>
</tr>
<tr>
<td>a whole bunch</td>
<td>1</td>
</tr>
<tr>
<td>so much</td>
<td>1</td>
</tr>
</tbody>
</table>
### Children's Descriptions of a Smaller Amount

<table>
<thead>
<tr>
<th>Description</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>only have n</td>
<td>70</td>
</tr>
<tr>
<td>less</td>
<td>37</td>
</tr>
<tr>
<td>just has n</td>
<td>19</td>
</tr>
<tr>
<td>not (doesn't have, or don't got) more than</td>
<td>16</td>
</tr>
<tr>
<td>(a) little</td>
<td>16</td>
</tr>
<tr>
<td>not as (so) many as</td>
<td>15</td>
</tr>
<tr>
<td>littlest</td>
<td>15</td>
</tr>
<tr>
<td>aren't (don't have, not) the same</td>
<td>12</td>
</tr>
<tr>
<td>a little bit</td>
<td>12</td>
</tr>
<tr>
<td>different</td>
<td>11</td>
</tr>
<tr>
<td>not enough</td>
<td>11</td>
</tr>
<tr>
<td>some</td>
<td>11</td>
</tr>
<tr>
<td>smaller</td>
<td>8</td>
</tr>
<tr>
<td>not (ain't no) fair</td>
<td>8</td>
</tr>
<tr>
<td>not (doesn't have) the same amount</td>
<td>7</td>
</tr>
<tr>
<td>not very much</td>
<td>7</td>
</tr>
<tr>
<td>wants more</td>
<td>7</td>
</tr>
<tr>
<td>not even</td>
<td>6</td>
</tr>
<tr>
<td>more smaller</td>
<td>6</td>
</tr>
<tr>
<td>doesn't have that much</td>
<td>5</td>
</tr>
<tr>
<td>only a few</td>
<td>5</td>
</tr>
<tr>
<td>not very many</td>
<td>4</td>
</tr>
<tr>
<td>doesn't have the most</td>
<td>4</td>
</tr>
<tr>
<td>only (just) a little</td>
<td>4</td>
</tr>
<tr>
<td>littler</td>
<td>3</td>
</tr>
<tr>
<td>doesn't have more</td>
<td>3</td>
</tr>
<tr>
<td>not as more as</td>
<td>2</td>
</tr>
<tr>
<td>just a (teeny) (little) bit</td>
<td>2</td>
</tr>
<tr>
<td>very little</td>
<td>2</td>
</tr>
<tr>
<td>not the same number</td>
<td>1</td>
</tr>
<tr>
<td>don't have a tie</td>
<td>1</td>
</tr>
<tr>
<td>doesn't have as much as</td>
<td>1</td>
</tr>
<tr>
<td>a tiny bit</td>
<td>1</td>
</tr>
</tbody>
</table>

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Children's Descriptions of Equal Amounts

<table>
<thead>
<tr>
<th>Description</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>both have ( n )</td>
<td>58</td>
</tr>
<tr>
<td>same</td>
<td>53</td>
</tr>
<tr>
<td>both have the same</td>
<td>27</td>
</tr>
<tr>
<td>each (both) have the same amount ( n ) on each (both) side</td>
<td>16</td>
</tr>
<tr>
<td>(both) equal</td>
<td>2</td>
</tr>
<tr>
<td>each got ( n )</td>
<td>2</td>
</tr>
<tr>
<td>same number</td>
<td>2</td>
</tr>
<tr>
<td>a tie</td>
<td>2</td>
</tr>
<tr>
<td>it's even</td>
<td>2</td>
</tr>
<tr>
<td>it's fair</td>
<td>2</td>
</tr>
<tr>
<td>they match</td>
<td>1</td>
</tr>
<tr>
<td>same groups</td>
<td>1</td>
</tr>
<tr>
<td>( n ) and another ( n )</td>
<td>1</td>
</tr>
<tr>
<td>( n ) here too</td>
<td>1</td>
</tr>
<tr>
<td>can't tell the difference</td>
<td>1</td>
</tr>
<tr>
<td>he could have half and</td>
<td>1</td>
</tr>
<tr>
<td>he could have half</td>
<td>1</td>
</tr>
<tr>
<td>both got so many</td>
<td>1</td>
</tr>
<tr>
<td>enough for both of them</td>
<td>1</td>
</tr>
<tr>
<td>an even number of</td>
<td></td>
</tr>
<tr>
<td>them on both sides</td>
<td>1</td>
</tr>
</tbody>
</table>

Other Descriptive Comments

- less more than
- this is less more than this
- this is more than the other and less too
- just two — just!!
- this one is better
- I can't tell the difference which one is which
- he don't got enough
- it's a tie
- this ain't no fair; this is fair
- this is not enough; this is enough; this is enough for them both
- it's not even; it's almost even; it's even
- there's an even number of them on both sides
- they both have a lot
APPENDIX D

Quantity-Comparative Vocabulary Used in the Seven Mathematics Series Examined

<table>
<thead>
<tr>
<th>Terms</th>
<th>Number of Series Using the Term in Kindergarten</th>
<th>Number of Series Using the Term in First Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>large, larger, largest</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>(not necessarily referring to amount)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>small, smaller, smallest</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>(not necessarily referring to amount)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>all</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>some</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>more</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>one more than</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>as many as</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>same number</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>different (number)</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>few, fewer, fewest</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>most</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>one fewer than</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>not any</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>alike</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>equal</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>pair</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>match</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>greater (than)</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>less (than)</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>lesser, least</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>difference</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>one less than</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>many</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>one greater than</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
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